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WATERWAYS CENTRE FOR FRESHWATER MANAGEMENT

POLLUTION OF URBAN WATERWAYS IN NAIROBI: A CASE STUDY OF MATHARE 4B VILLAGE, NAIROBI, KENYA.

A thesis presented in partial fulfilment of the requirements for the degree of Master of Water Resource Management at the University of Canterbury, New Zealand

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Abstract

Nairobi's urban waterways have been exposed to extreme degradation as a result of uncontrolled urban development. Urbanisation rates have exceeded economic growth leading to an urbanisation of poverty associated with the proliferation of informal settlements. These settlements are characterised by poverty, inadequate sanitation and solid waste services, as well as insecure land tenure. These informal settlements have proliferated mainly along Nairobi's waterways, exposing them to pollution. Pollution in the city has rendered the water in the entire Athi River basin non-potable and a significant health risk to all users.

The main aim of this research was to investigate why and how residents of informal settlements interact with urban waterways to help inform the development of sustainable management practices. This included reviewing the role of relevant government agencies responsible for the management of urban waterways. The research adopted a case-study approach for in-depth analysis incorporating both quantitative and qualitative research methods.

The study revealed that residents of Mathare 4B, the case study area, have little sentimental attachment to urban waterways, leading to little or no incentive to care for them. It also revealed high microbial contamination associated with untreated or partially treated sewage effluent. The study established presence of youth groups in Mathare 4B which have attempted to protect the adjacent Mathare River through various means. However, these youth groups lacked adequate tools and protective gear to enable them conduct successful river management.

The current hierarchical management structure of Nairobi's urban waterways has not been effective in addressing the pollution dilemma. The study therefore explored an alternative systems approach to managing waterways based on the panarchy framework. Two major gaps associated with the degradation of waterways were identified as: little or no engagement with the urban communities, and a rigid, ineffective, hierarchical government management approach. The study thus recommended a 'commoning' of the urban waterways as one way of effectively engaging local communities in sustainable waterways' management. The study also recommended that relevant government agencies play a facilitatory role by empowering urban communities to manage waterways at the settlements' level. This represents one of the best chances for rehabilitating and sustainably managing Nairobi's waterways.

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Acronyms

AFDB – African Development Bank

ARRP – Athi River Restoration Programme

ASALs – Arid and semi-arid lands

AWSB – Athi Water Services Board

CAACs – Catchment Area Advisory Committee

CBD – Central Business District

CFU – Colony Forming Units

CPRs – Common Pool Resources

EMCA – Environmental Management and Coordination Act

FGD – Focus Group Discussion

GoK – Government of Kenya

GDP – Gross domestic product

GWP – Global Water Partnership

HEP – Hydro-electric power

IWRM – Integrated Water Resource Management

KNBS – Kenya National Bureau of Statistics

MCA – Member of the County Assembly

MDG – Millennium Development Goals

MPI – Multi-dimensional poverty index

NRB – Nairobi River Basin

NCCG – Nairobi City County Government

NCWSC – Nairobi City Water and Sewerage Company

NEMA – National Environment Management Authority

NGO – Non-governmental organisation

NYS – Youth Services

TARDA – Tana and Athi Rivers Development Authority

UN – United Nations

UNDP – United Nations Development Programme

UNEP – United Nations Environmental Programme

UoN – University of Nairobi

UCB – University of California Berkeley

VIP – Ventilated improved pit latrines

WC – Water closet

WRMA – Water Resource Management Authority

WRUAs – Water Resource Users Association

CHAPTER 1: INTRODUCTION

Recently, there has been growing public outrage about the pollution of urban waterways[1] in Nairobi city. This pollution has rendered the water throughout the Athi River basin non-potable and poses a significant health risk to all users (Nzuma, 2016). Its effects have been so dire that the government issued an official statement urging downstream communities to abstain from using water flowing from the city for domestic and agricultural purposes (Muiruri, 2013). This is despite the fact that the Athi River is the main source of water for these downstream areas, which are located in a zone of arid and semi-arid lands (ASALs) receiving less than 500 mm rainfall annually (Muiruri, 2013). In addition, it is ironic that the pollution of urban waterways in Nairobi is happening at a time when the city is facing acute water shortages leading to water rationing (Mutavi, 2016; Nyamori, 2016). The pollution of urban waterways in Nairobi has been extensively studied in the last two decades, with main focus on the statistical analysis of pollutants and on the effects of adjoining urban land uses on water quality. Water monitoring data collected within the Nairobi River Basin has indicated high pollution levels from sewage and industrial effluent (Musyoki, Suleiman, Mbithi, & Maingi, 2013). However, these monitoring exercises have not been backed up with effective remedial measures to reduce pollution, as evidenced by the current degraded state of urban waterways in Nairobi as reported by Nzuma (2016) and others.

This thesis therefore examines the pollution of urban waterways with a specific focus on informal settlements in Nairobi city; the causes and effects of the pollution, as well as possible pollution management options. It does not seek to portray the informal settlements as 'pariahs' in regard to pollution of the rivers but rather seeks to form an in-depth understanding into the circumstances under which it happens. The study recognises that there are many other diverse pollution sources within the city such as industries, markets, businesses, and other formal human settlements (Karisa, 2010; Muiruri, 2013; Nzuma, 2016). The focus on informal settlements is based on the fact that they have been marginalised over the years with little or no provision of sanitation and solid waste services, as well as facing a myriad of challenges including poverty

[1] In this thesis, the phrases "urban waterways" has been used interchangeably with rivers and represents the same thing

and insecure land tenure. In addition, almost all of Nairobi's informal settlements have sprouted along urban waterways and have been identified as the major sources of pollution for these waterways (Karisa, 2010; Wachira, 2015). A map of of informal settlements in Nairobi (figure 1 below) shows how these are mainly situated along urban waterways. The pollution of Nairobi's urban waterways is a phenomenon that adversely affects water quality for users both within the city and downstream into the hinterlands.

1.1 Research background

Clean, safe, and adequate water is important for human survival as well as to support vital aquatic and terrestrial ecosystems (Palaniappan et al., 2012). However, the availability of global freshwater resources is increasingly threatened by anthropogenic stressors, including rapid population growth, pollution, agro-industrial development, and increased urban run-off (DellaSala, 2013; Palaniappan et al., 2012). It is estimated that approximately a billion people globally do not have access to clean drinking water, mainly in the developing world (DellaSala, 2013; Gray & Stewart, 2009). Inadequately treated sewage, industrial effluent, and agricultural run-off contaminate the world's water, leading to an estimated 1.8 million annual child deaths as a consequence of unsafe water and poor sanitation – a mortality figure higher than from all forms of annual global violence, including war (Gray & Stewart, 2009; Palaniappan et al., 2012; Simonovic, 2002; UNDP, 2006).

The global water crisis can be put into perspective by looking at the distribution of water resources in the world. Global water resources consist of 96.6% seawater and 3.4% freshwater (Lécuyer, 2013). Of the 3.4% freshwater, 48.7% is groundwater and 50.7% is trapped in icecaps and glaciers, while only 0.5% is available as surface water. The latter represents the most easily accessible source for use by humans and other organisms. The largest proportion of surface water is found in lakes (79%); rivers represent 1%, and the remaining proportion exists as water vapour and moisture in soils (Lécuyer, 2013). The water directly available for human use is limited to surface water sources from lakes and rivers; groundwater is only available through pumping and saline water from oceans only by desalination.

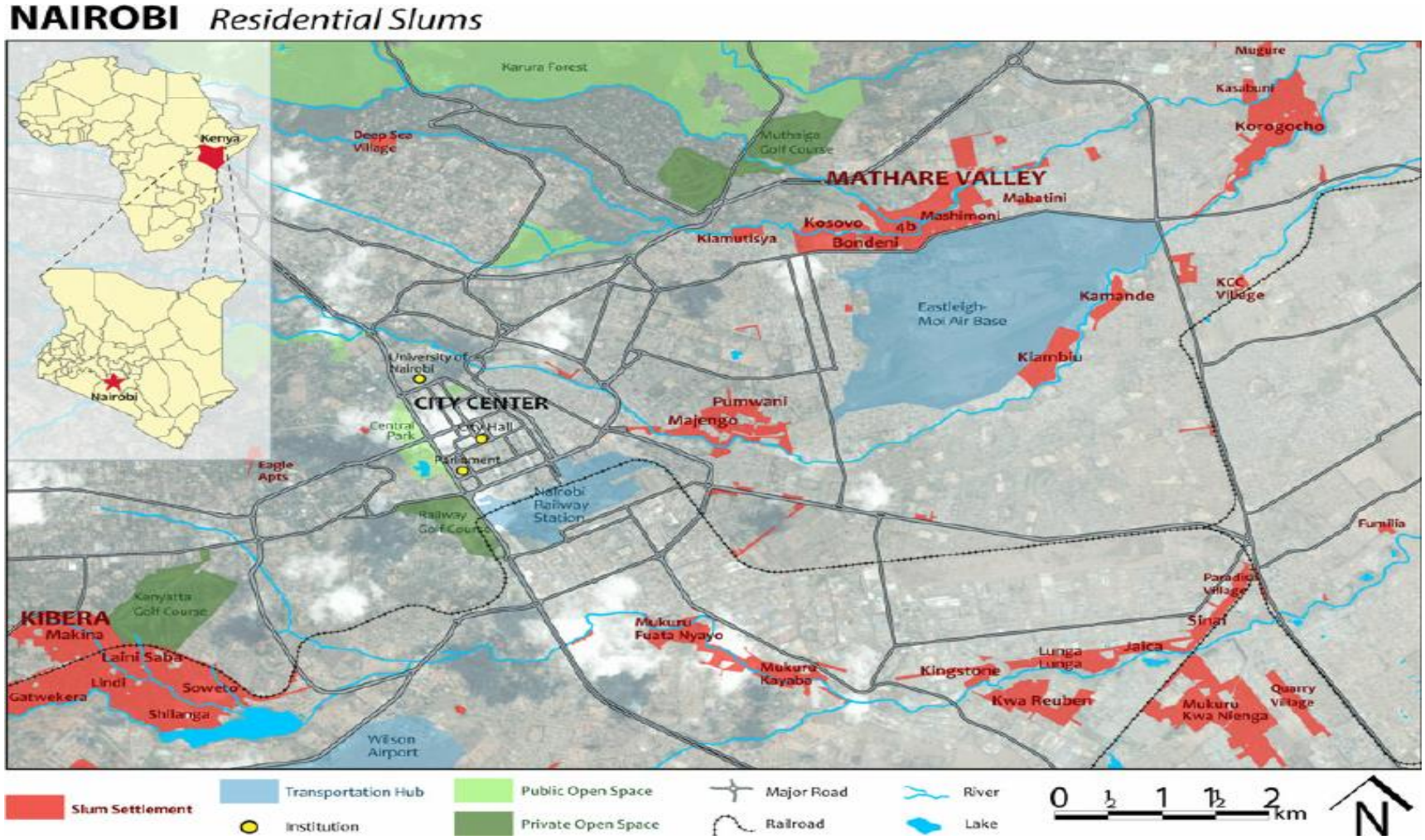


Figure 1: Informal settlements/residential slums in Nairobi (UoN & UCB, 2011, p. 7)

The rivers are particularly important as they are easily accessible and provide water for domestic purposes, irrigation, recreational opportunities, and industrial activities, as well as serving as fisheries and a source of other foodstuffs (Miller & Miller, 2007).

The distribution of global water resources illustrates the importance of managing the limited proportion of directly accessible freshwater resources from lakes and rivers. Unfortunately, as demonstrated by earlier studies and by water simulation models, the freshwater readily available for human use, already meagre in percentage, is increasingly being polluted, further reducing the amount available against a rapidly increasing population. According to Simonovic (2002), countries throughout the world are dealing with increasing demand for freshwater on one hand and increasingly polluted water supplies on the other. This is attributed to rapid population growth in the face of a water supply that is no greater than it was thousands of years ago when the world population was 3% of the current population size (Simonovic, 2002).

Using the WorldWater simulation model,[2] Simonovic (2002), demonstrated that water is a vital resource on the global scale as it affects food production, total population growth, and industrial development. Simulations of the model reached an important conclusion:

> Pollution of water is the most important future issue on the global scale. In spite of the rhetoric of many water experts, results of *WorldWater* simulations are explicitly, and for the first time, bringing water pollution to the forefront as the most alarming issue that needs attention of world population, water experts, and policy makers. (Simonovic, 2002, p. 266)

Simonovic's conclusion is supported by Miller and Miller (2007), who bring in the perspective of sewage pollution. They point out that for thousands of years humans have used rivers as a natural sewer system. Initially, aquatic degradation was minimal as the adverse effects of discharging sewage were negated by a dilution effect.[3] This effect was weakened and even negated with the onset of Industrial Revolution of the 19th century, accompanied by an increase in global population from 1.5 billion in 1880 to 6 billion in 1999. This resulted in increased

[2] This model uses a system dynamics approach to integrate the water resources sector (quantity and quality) with sectors that drive industrial growth: population, agriculture, economy, non-renewable resources, and persistent pollution.

[3] The dilution effect refers to the natural process through which a river breaks down biodegradable wastes as it flows eventually reducing it to undetectable levels.

sewage discharge along entire river continuums as well as the introduction of non-biodegradable contaminants from industrial activities, such as chemicals and heavy metals.

In Africa, the water crisis is aggravated by poverty, drought, and climate variability, in addition to the aforementioned global anthropogenic stressors (Oyebande, 2001). Within the African continent, 45% is classified as arid or extremely arid with 33% as humid or sub-humid. The humid regions of the continent are at risk and face imminent desertification as a result of climate change/variability and deforestation. It is estimated that by the year 2020, nearly 250 million people in Africa will be exposed to water stress as a result of climate change (UNDP, 2015). The pollution of streams, rivers, and lakes, particularly in the receiving water bodies in urban areas, has also been identified as a major concern, with frightening health impacts (Oyebande, 2001). Diseases and productivity losses associated with unclean water and poor sanitation amount to 5% of gross domestic product (GDP) in sub-Saharan Africa (UNDP, 2006).

In Kenya, ASALs constitute 89% of the total land area (as shown in figure 2) and are home to about 14 million people (GoK, 2015). Marshall (2011) observes that water scarcity in Kenya has been a major issue caused by droughts, poor water management, and an increase in water demand resulting from high population growth. In a country of over 40 million people, 17 million (43%) do not have access to clean water (Marshall, 2011). The situation gets worse for the country's urban population: the majority of the urban poor only have access to polluted water, resulting in outbreaks of water-related diseases, especially in informal settlements (Marshall, 2011; Tibaijuka, 2009).

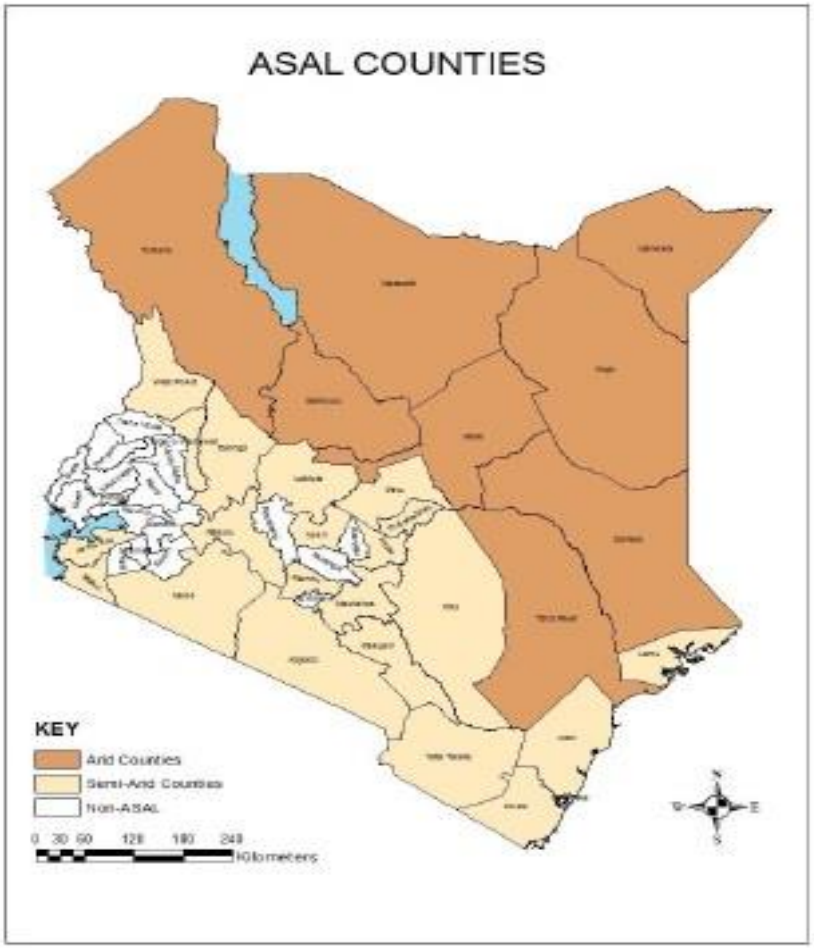


Figure 2: Arid and semi-arid counties in Kenya (GoK, 2015, p. 4).

1.2 Problem statement

Previous research conducted within the Nairobi River Basin has shown that the pollution of the rivers traversing Nairobi city is adversely affecting downstream communities that rely on the water for domestic and agricultural use (Musyoki et al., 2013). While Nairobi city is located in a humid region with considerable rainfall, the communities downstream are in a semi-arid zone prone to perennial droughts. The Nairobi River represents the major source of water in this downstream region, where it is usually used in an untreated state for domestic and agricultural purposes. Previous studies reveal failure on the part of relevant authorities to provide adequate sanitation infrastructure as the major cause of high pollution levels in the Nairobi Basin rivers (Karisa, 2010; Wegelin-Schuringa & Kodo, 1997).

The three prominent polluters of the Nairobi River Basin have been identified as the informal settlements, industrial activities, and the city's sewage treatment plant (Karisa, 2010; Muketha, 2014; Musyoki et al., 2013). Of the three, the most complex to deal with is the informal settlements category due the complexity of the socio-economic and political issues involved. The situation is aggravated by the deliberate exclusion of informal settlements from city plans, which means they are rarely provided with basic infrastructure and services due to their perceived illegitimacy. This situation has had negative environmental and health impacts not only in the settlements but also across the city and even further outside it.

Informal settlements in Nairobi city represent the major source of pollution in the rivers traversing the city mainly due to inadequate or inexistent sanitation facilities (Wegelin-Schuringa & Kodo, 1997). These settlements are located along river valleys and electricity wayleaves and near hazardous industrial activities on both private and public land (Githira, 2016; Wegelin-Schuringa & Kodo, 1997). Karisa (2010) and Muketha (2014) further observe that riparian reserves along the three major rivers in Nairobi have been encroached mainly by informal settlements. As these settlements lack vital sanitation services such as sewer lines and solid waste management, the adjacent rivers have been used for discharging raw sewage and solid waste, as shown in figure 3 below (Mwau, 2012). The city's sewage treatment plant and industries within the city also discharge partly treated sewage and industrial effluent into the rivers. These factors together make the Nairobi River Basin the most polluted in the country (Karisa, 2010; Muketha, 2014).

A recent study assessing levels of human pathogens associated with the Nairobi and Athi Rivers determined that the river water is not potable and poses health risks to downstream communities (Musyoki et al., 2013). The assessment showed the presence of various bacterial types such as *E. coli* and *Salmonella* Typhi after the Nairobi River had passed through informal settlements. The study also revealed that the concentration of *E. coli* in the Nairobi River increased tenfold after the discharge of effluent by the city's treatment plant, which is downstream of the informal settlements. After passing through the sewage treatment plant, Nairobi River drains into the Athi River, Kenya's second longest river. Downstream of the confluence of the two rivers, the study found high levels of bacterial pathogens, suggesting the role played by surface run-off, informal

settlements, and the city's treatment plant in the microbial pollution of this river continuum (Musyoki et al., 2013).

Figure 3: Improvised toilets discharging directly into the river in Mathare settlement (Mwau, 2012).

1.3 Background to the study area

This section provides a brief background of Nairobi city as well as the Mathare informal settlement, which was chosen as a case study area for this research. This section also provides a brief description of the rivers constituting the Nairobi River Basin (NRB), the sources of the rivers, and the urban landscape the rivers flow through before exiting the city and joining Athi River. Urban waterways in Nairobi are part of the Athi River catchment, constituting the upper catchment or what would be termed as the upstream region.

Kenya is a country in the East African region covering a land mass of approximately 580,367 km^2. It is bordered by Somalia and the Indian Ocean to the east, Tanzania to the south, Uganda to the west, and South Sudan and Ethiopia to the north. According to the 2009 census, Kenya had a population of approximately 39 million people (KNBS, 2010). It is estimated that by the year 2015, the population had increased to 46 million people (UN, 2015). Kenya consists of 47 county governments, one of which is the Nairobi City County Government (NCCG) (figure 4 below). Nairobi is also the capital city of the country.

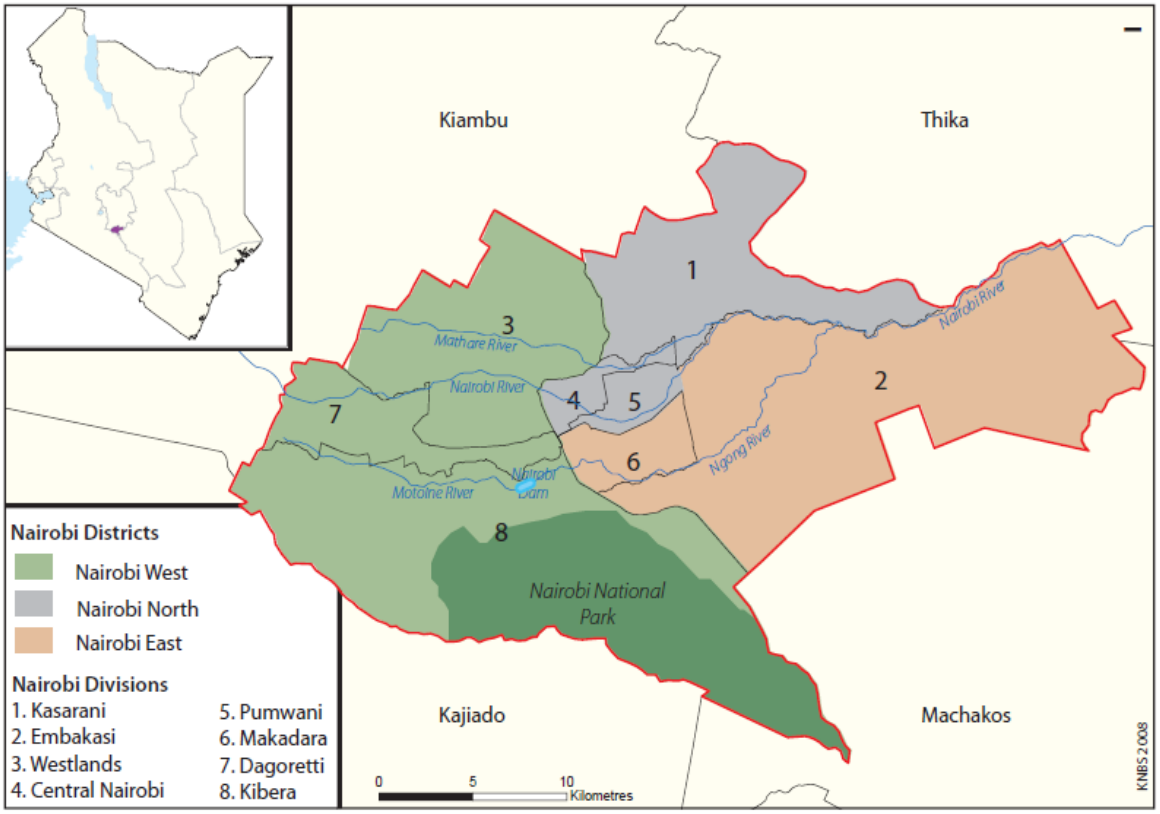


Figure 4: Districts map of Nairobi City County (UNEP, 2006, p. 5)

Nairobi city covers an area of 696 km^2 and had total population of approximately 3 million people in 2009 with a population density of 4,515 people per km^2 (KNBS, 2012). The city is the country's financial hub, but its informal settlements are also home to some of the country's poorest people. It is estimated that 60% of the total population in Nairobi live in informal settlements on less than one-sixth of the city's total land area (Nabutola, 2011). The population of Nairobi has experienced dramatic growth, increasing from around 4,000 in 1900 to 859,000 in 1979 and over 3 million by 2010. Figure 5 below shows the historical population trends and future projections for Nairobi. Continuing rapid population increase in Nairobi does not bode well for a city already experiencing water shortages.

According to Kenya's census data, in 2009 one out of every three Kenyans lived in an urban area, representing 32% of the total population or 12.5 million Kenyans. Rapid urbanisation trends observed in Kenya over the years, a result of population increase and rural-urban migration (Nabutola, 2011), have led to formation of informal settlements. Nairobi is home to a

number of such settlements, which have sprouted up around the industrial areas, river valleys, and road and railway reserves. These settlements lack vital basic services and infrastructure and are characterised by deplorable living conditions, especially where water and sanitation are concerned.

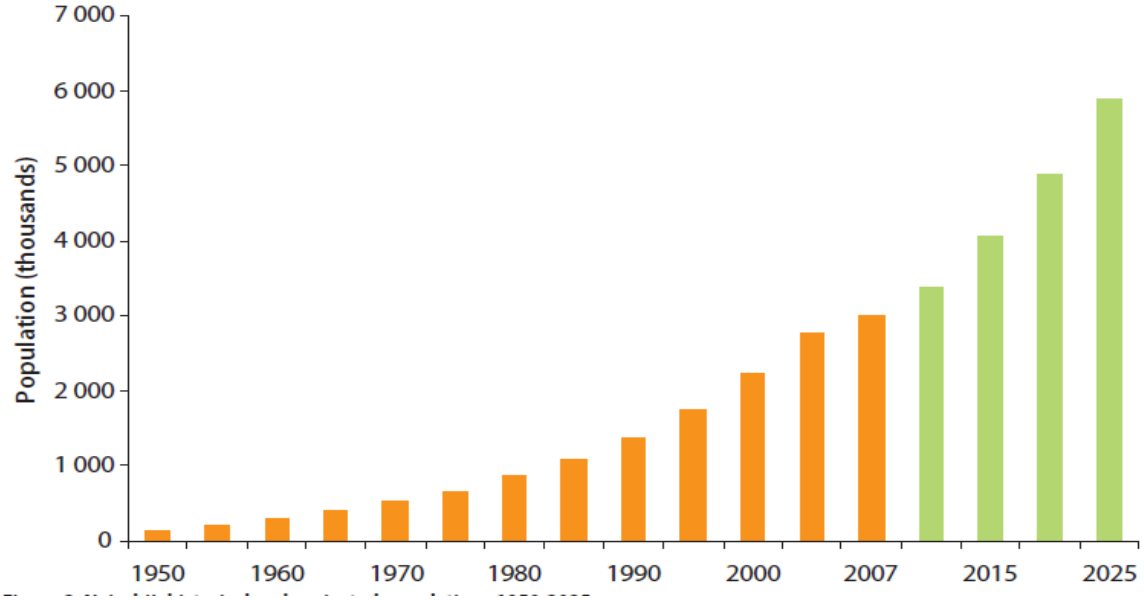


Figure 5: Past and projected population growth in Nairobi (KNBS, 2010)

Mathare is one of Nairobi's informal settlements, with an estimated population of 200,000 (UoN & UCB, 2011). It is the second-largest in Kenya after Kibera. The settlement lies within the valley of the Mathare and Gitathuru Rivers and comprises of thirteen villages: Mashimoni, Mabatini, Village No. 10, Village 2, Kosovo, 3A, 3B, 3C, 4A, 4B, Gitathuru, Kiamutisya, and Kwa Kariuki (UoN & UCB, 2011). Of importance to this research is Mathare 4B, which was selected as a case study area. Mathare 4B village has an estimated population of 5,600 occupying an area of approximately 0.061 km^2. It is located on government land which is in essence the riparian zone of the Mathare River. It is estimated that 87% of residents in the entire Mathare settlement are tenants while 17% are structure owners (UoN & UCB, 2011). As with many other informal settlements in Kenya, Mathare 4B is characterised by congestion, inadequate water and sanitation provision, inadequate solid waste management services, high poverty levels, and inadequate access routes (Githira, 2016; Muketha, 2014; UNEP, 2006).

Figure 6 below geographically locates the areas of study discussed in this section. It is also important to discuss the urban waterways within the Nairobi River Basin so as to be able to establish how various urban land uses interact with the urban waterways.

The Nairobi River Basin constitutes the upper catchment of Athi River, Kenya's second longest river at approximately 591 km in length. It covers a basin area of approximately 38,000 km^2 with an estimated population of 8 million people (WRMA, 2016). It transects 11 counties: Nairobi, Kiambu, Machakos, Makueni, Kitui, Kajiado, Kilifi, Taita Taveta, Nyandarua, Kwale, and Mombasa (figure 7 below).

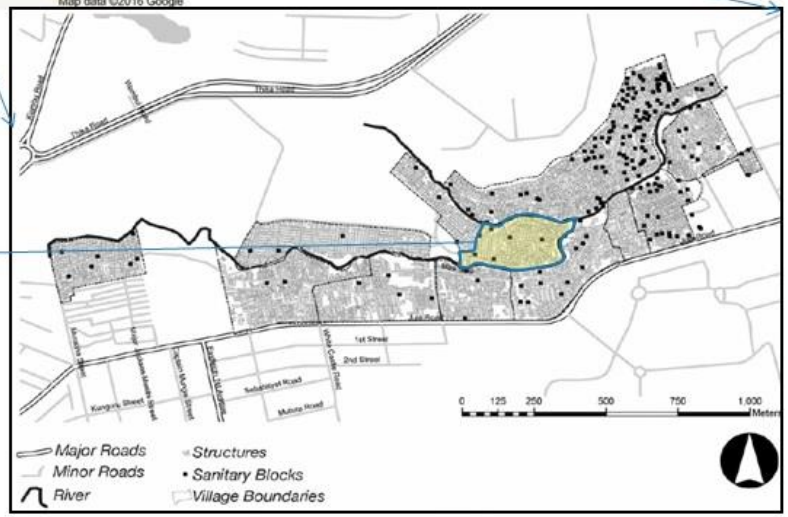
The Nairobi River Basin (map in figure 8 below) comprises four rivers: the Nairobi, Ngong, Motoine, and Mathare. These rivers merge to form the larger Nairobi River before exiting the city. The Nairobi River then drains into the Athi River, which eventually drains into the Indian Ocean via the southeastern part of Kenya. The sources of Nairobi's urban waterways are the Kikuyu Springs, in the north western part of Nairobi around 30 km from the city centre, and Ngong Hills, around 35 km west of the centre. The urban waterways flow southeast into Nairobi city where they pass through urban lands put to many kinds of uses, such as industrial areas, informal settlements, informal markets, and motor vehicle repair garages. They converge into the main Nairobi River, collecting treated sewage from the Ruai treatment plant before exiting the city. The river then flows through a series of quarries and then on to Fourteen Falls, a major recreational site for both domestic and foreign tourism. It eventually joins the Athi River, the main source of water for domestic use to downstream communities, which lie in a zone of ASALs. In these communities the water is mainly used in an untreated state.

Africa (http://ontheworldmap.com)

Kenya (http://kenyamap.facts.co)

Nairobi (Google maps, 2017)

Mathare 4B
Population – 5,681
Land area – 6.1 ha



Mathare settlement (U.o.N & U.o.C.B, 2011)

Figure 6: Research location context

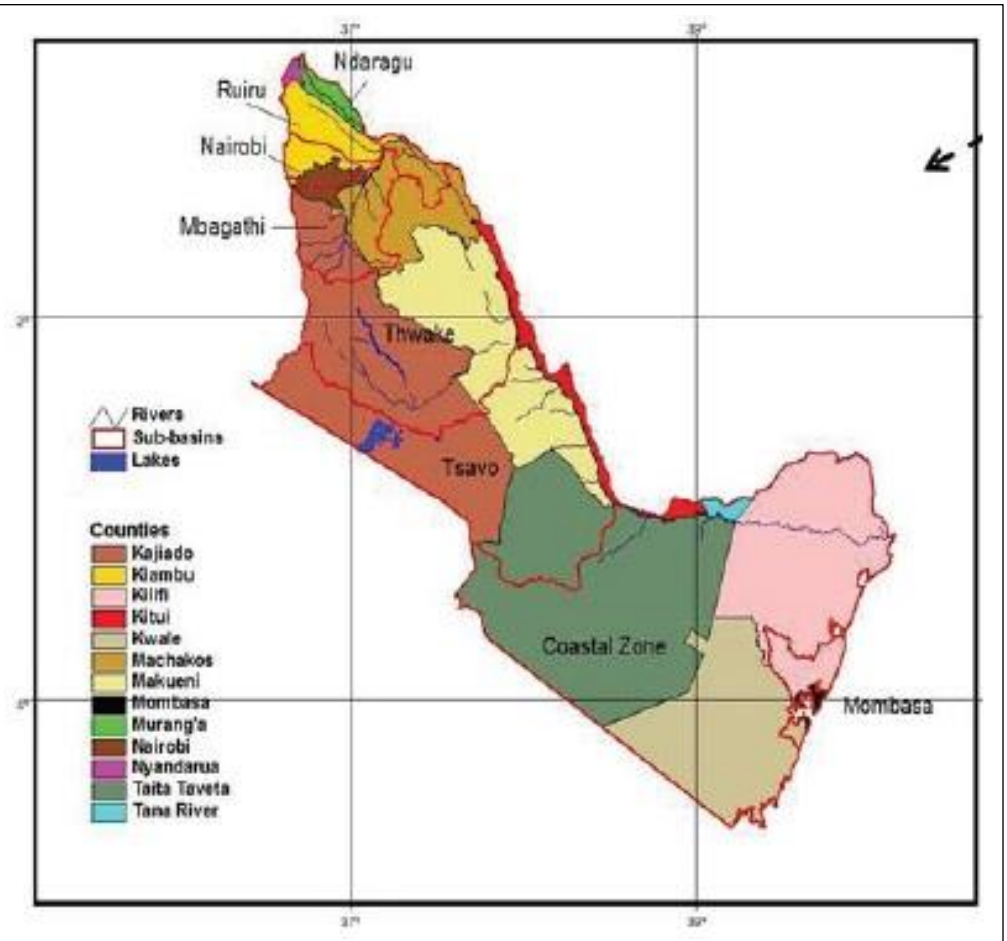


Figure 7: Counties within the Athi River Basin (WRMA, 2016)

The environment through which Nairobi's urban waterways flow can be divided into three zones: the upper reaches, the middle zone, and the lower reaches. They transect various urban land uses and are exposed to a variety of contaminants on their journey from their sources and across the city.

The upper reaches of the Nairobi River Basin consist of areas around the river's sources at Kikuyu Springs and the Ngong Hills. The upper reaches are sparsely settled and the land is mainly used for subsistence farming. There are no major industries in this section of the catchment. However, before Nairobi River enters the capital city, it passes through a major market centre which hosts a number of abbatoirs. These represent the river's first major point source of pollution (Tyman, 2006) and have been known to discharge blood and sludge into one of the tributaries of Nairobi River, the Kabuthi, as shown in figure 9 below (Muturi, 2013).

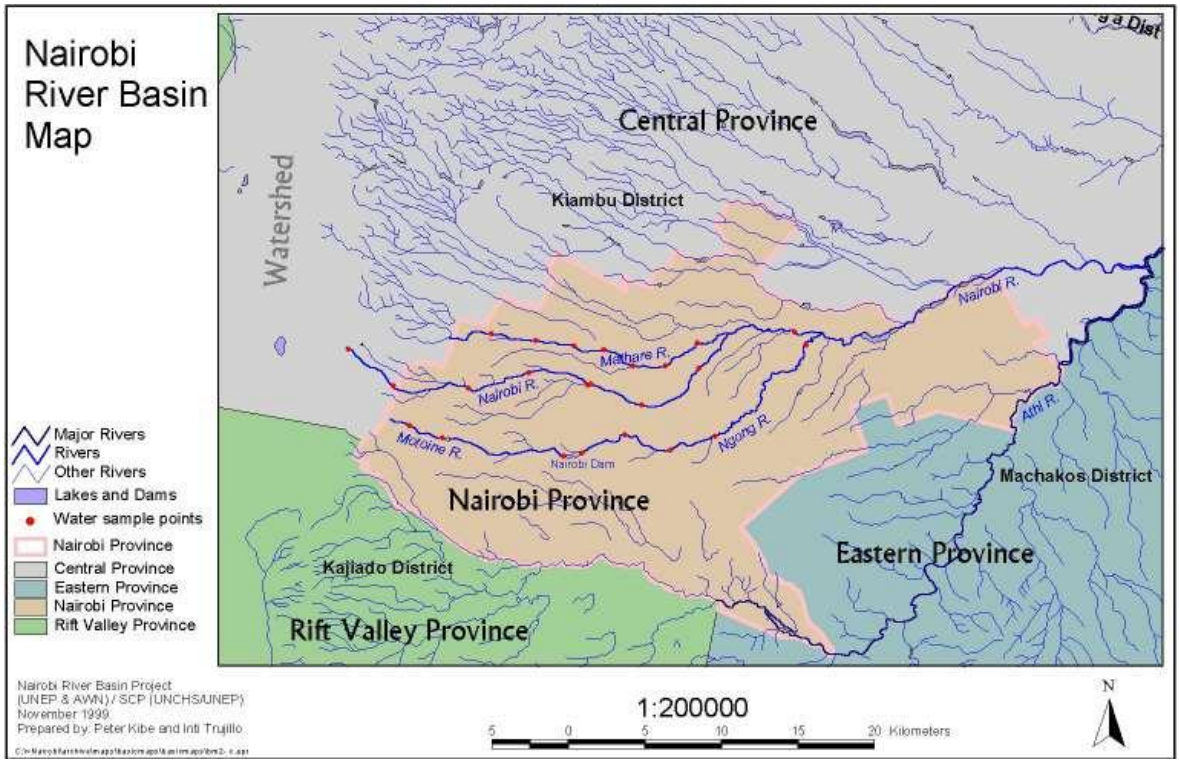


Figure 8: The Nairobi River Basin (UNEP, 2017)

Figure 9: Blood and offal from abbatoirs discharged into the Kabuthi tributary (Tyman, 2006).

At the middle zone, the urban waterways enter the city and pass through an area characterised by several different land uses: recreational (the Nairobi Arboretum city park), the central business district, a large informal market (Gikomba), garages and light industry, and a series of informal settlements. The park and CBD have not had significant negative adverse effects on the waterways as compared to the other land uses in this zone. This is attributed to these uses having observed and maintained riparian zones along the river and also being served adequately with infrastructure for both solid and wastewater disposal (Muketha, 2014). On the other hand, informal settlements in this zone are a major source of pollution, discharging both solid and liquid wastes into the waterways. This is attributed to inadequate provision of basic sanitation infrastructure and services (Karisa, 2010; Musyoki et al., 2013).

The lower reaches pass by a series of quarries and the Nairobi sewage treatment plant. In most cases, the quarries are abandoned and are used as landfill sites and strewn with solid waste (Muketha, 2014). Wind and heavy rains have been known to carry this waste (especially polyethene bags) into the river. The quarries that are operational are a source of sediment into the river transported by wind and rain run-off.

The other significant land use in the lower reaches of the river is the Nairobi sewage treatment plant. According to the Nairobi City Water and Sewerage Company (NCWSC), the facility treats about 80,000m^3 of wastewater per day, equivalent to about 80% of the total wastewater generated in Nairobi city. The wastewater is treated through two processes: physical treatment and biophysical treatment. The treated water is then released to the Nairobi River and flows downstream to join the Athi River.

The challenges facing the treatment plant which have negatively affected the effectiveness of its treatment process have been associated with the dumping of overloaded effluent into the sewer system which does not meet required discharge standards, including non-biodegradable materials, polyethene bags, large physical materials, high levels of nitrates and phosphates, grease, and heavy metals (NCWSC, 2015). These challenges include the breakdown of treatment plant machines, reduced effectiveness of the ponds, and reduced performance of biological microorganisms due to heavy metals, together leading to a poor final quality of treated effluent. As the wastewater treated and released into Nairobi River from this plant is of a very poor quality, it has the potential of having adverse effects on communities further downstream.

The diverse urban landscape presents many challenges to the Nairobi River Basin, mainly associated with pollution and the subsequent deterioration of water quality. Various urban land uses contribute to the high pollution levels observed within the rivers, and the effects of this are increasingly felt by the downstream communities that rely on this water for various uses. This research focuses on the pollution of the Nairobi River by adjacent informal settlements, which perhaps represent a more diffuse, non-point source of pollution for the river system. The fact that almost all informal settlements in Nairobi are located along river valleys is a justification for this thesis as a means of working towards an in-depth understanding of how such a complex challenge might be addressed.

1.4 Research aims and objectives

The aim of this research is to investigate why and how informal settlement residents interact with urban waterways to help inform the development of sustainable management practices. This includes reviewing the role of relevant government agencies directly and indirectly responsible for the management of urban waterways. The research has identified a section of the Mathare informal settlement in Nairobi, Kenya as a suitable case study.

1.4.1 Objectives

1. Conduct interviews and focus group discussions to explore how residents perceive and interact with urban waterways.
2. To establish, from information provided by residents and key informants, the major causes of urban waterways pollution and how best to mitigate it.
3. To document observed uses of urban waterways traversing informal settlements and how these affect water quality.
4. To collect and analyse water samples for bacterial pathogens along Mathare informal settlement and further downstream.
5. To review urban waterways management practices with the view of informing sustainable management.

1.4.2 Research questions

In order to achieve the above objectives, the fieldwork will address the following research questions:

1. What are the perceptions of informal settlement residents in relation to urban waterways and how do they interact with the waterways?
2. What are the major causes of pollution of the urban waterways adjacent to informal settlements?
3. What functions do the urban waterways serve for informal settlement dwellers?
4. How does pollution of urban waterways affect water quality for downstream communities?
5. What measures can be put in place to reduce the pollution of urban waterways and promote their sustainable management?

1.5 Thesis structure

This thesis is organised under seven chapters. Chapter 1 introduces the research problem, provides the geographic context of the research location, and gives a brief overview of the Nairobi River Basin. Chapter 1 also contains the objectives and research questions for this study. Chapter 2 discusses the challenges posed by urbanisation in regard to the proliferation of informal settlements and the problems of sanitation they face. Chapter 3 discusses the management of urban waterways with a focus on informal settlements in Nairobi and explores other sustainable management approaches based on the systems theory. Chapter 4 discusses the research methodology adopted to conduct fieldwork for this study. Chapter 5 presents the results of the research as well as their implications on the management of urban waterways in Nairobi. Chapter 6 discusses and synthesises the findings of this study based on the fieldwork data obtained as well as the literature reviewed. Chapter 7, the concluding chapter, reflects on the findings of the study and proposes recommendations for the sustainable management of urban waterways in Nairobi.

CHAPTER 2: URBANISATION, INFORMAL SETTLEMENTS, AND THE PLIGHT OF URBAN WATERWAYS

The introductory chapter gave a brief overview of the research problem and provided a description of the study area. Water pollution has been identified as the most important future issue faced by humanity on the global scale (Simonovic, 2002). This is at a time when urban waterways in Nairobi are facing unprecedented pollution levels which have led to downstream communities being advised not to use water flowing from the city. The population statistics for Nairobi as presented in chapter 1 indicate a rapid population increase in a city that is already experiencing inadequate provision of sanitation services and solid waste management. These two factors have placed Nairobi's urban waterways under extreme pressure. This chapter therefore discusses the challenges of urbanisation in regard to the proliferation of informal settlements, inadequate sanitation services, and the effects of these on urban waterways.

The literature reviewed in this section provides the basis for understanding how urbanisation trends in Nairobi have ultimately led to the degradation of its urban waterways. The discussions in this chapter focus mainly on urbanisation associated with poverty, the proliferation of informal settlements, the challenge of service provision for these settlements, and the effects of these circumstances on urban waterways. An in-depth understanding of the nature of the informal settlements is important as it reveals the relationship between these settlements, as a major urban land user, and the urban waterways in Nairobi. This chapter therefore partly addresses research questions two and three of this thesis: firstly, *what are the major causes of pollution of the waterways adjacent to urban informal settlements?* And secondly, *what functions do the urban waterways serve for informal settlement dwellers?*

2.1 Urbanisation and informal settlements

Urbanisation has been termed as the world's most concrete manifestation of the changes in global human settlement patterns (UN-HABITAT, 2010b; Zhang, 2016). It is defined as "a demographic, ecological, sociological, and economic phenomenon that concentrates populations in urban areas and has potential to either stimulate or retard growth and development in these areas" (Cobbinah, Erdiaw-Kwasie, & Amoateng, 2015a, p. 1). This definition captures the complexity of urbanisation throughout the world irrespective of whether it is occurring in developing or developed regions.

Urban areas are ideally viewed as places of prosperity where people can realise their dreams, and aspirations and turn their ideas into realities (UN-HABITAT, 2013). Urbanisation acts as an engine of growth for countries, improving their socioeconomic standards thus making them more advanced, developed, and rich (UN-HABITAT, 2013). While these views hold true for some parts of the world, others have experienced more negative effects of urbanisation and urban areas. Most countries in the developing world have been subjected to lopsided urban development characterised by marginalisation, deprivation, inequality, and exclusion (Cobbinah et al., 2015a; UN-HABITAT, 2013). Under these circumstances, urbanisation has instead led to unprecedented poverty and a glaring disparity between the rich and the poor in developing nations.

Inequality and unequal opportunities have pushed many people into informal settlement areas, which lack adequate infrastructure and services and are characterised by high incidences of poverty and squalid living conditions (Cobbinah, Erdiaw-Kwasie, & Amoateng, 2015b; UN-HABITAT, 2013; Zhang, 2016). Informal settlements, also known as slums, can be described as locations in urban areas where the poor are concentrated in high-density settlements and are living in sub-standard conditions (Githira, 2016). A more comprehensive definition of informal settlements that captures these substandard living conditions is provided by UN-HABITAT:

> Informal settlements are residential areas where 1) inhabitants have no security of tenure vis-à-vis the land or dwellings they inhabit, with modalities ranging from squatting to informal rental housing, 2) the neighbourhoods usually lack, or are cut off from, basic services and city infrastructure and 3) the housing may not comply with current planning and building regulations, and is often situated in geographically and environmentally hazardous areas. In addition, informal settlements can be a form of real estate speculation for all income levels of urban residents, affluent and poor (UN-HABITAT, 2015)

The definition provided by UN-HABITAT captures the high level of depravity and exclusion, subjected to informal settlements. More often than not, informal settlements do cause environmental degradation due to inadequate sanitation infrastructure and services and other negative prevalent conditions as described above. Urbanisation that leads to a proliferation of informal settlements has been termed ‘urbanisation of poverty’ or unsustainable development (Cobbinah et al., 2015b; Zhang, 2016).

Urbanisation of poverty occurs when a country's phenomenon of urbanisation outpaces economic development, leading to an increase of poverty in towns and cities (Zhang, 2016). This has been the trend in developing nations where, in a relatively short period of time, people have migrated in large numbers from rural to urban areas, leading to an increase of poverty in towns and cities (Ravallion, 2002; Zhang, 2016). Poverty in developing countries can be described in economic, social, and environmental terms. Economically, it is defined using the World Bank's poverty indicator of living on less than US$1 per day; socially, it is described using welfare indicators such as infant mortality, low life expectancy, and school enrolment; and environmentally, it has been defined as overreliance of the poor on natural resources leading to depletion and environmental degradation (Cobbinah et al., 2015a).

Poverty in Kenya has been described as "a state of inability to obtain a certain minimum level of consumption of food and essential non-food items universally considered adequate to satisfy the minimum requirements for human sustenance" (KNBS, 2008, p. 11). The Kenyan government has used a range of different poverty measures based on consumption and expenditures. They include the *food poverty line*, which considers the cost of consuming 2,250 kilocalories per adult equivalent per day, the *absolute or overall poverty line* in regard to survival food needs and basic non-food needs, and *hard-core poverty* in reference to households that would not meet their minimum nutritional requirements even if they allocated all their income to food (KNBS, 2008). Therefore, households are considered to be 'food poor' if they cannot meet all their nutritional needs due to expenditure on other non-food essentials such as rent, 'absolute poor' if they cannot meet their nutritional and other basic requirements, and 'hard-core poor' if they are unable to meet their basic food needs even by foregoing other essentials.

Another international measure of poverty that perhaps best captures the poverty situation in informal settlements in Kenya is the multi-dimensional poverty index (MPI). The MPI includes other parameters apart from food and monthly incomes and expenditures to define poverty in a broader sense, factoring in other indicators such as education, health, and standard of living (as summarised in table 1). Of importance to this study are the 'standard of living' parameters which capture the infrastructure and service provision deficiencies in informal settlements in Nairobi, and in particular, the sanitation indicator. According to the MPI, a household is deprived if the sanitation facility they have is not improved or is improved but shared with other households

(Alkire, Conconi, & Roche, 2012). This holds true for the research case study area, the Mathare settlement, as revealed by various authors (Githira, 2016; Muketha, 2014).

Studies conducted in Mathare reveal that only 17% of residents have access to a private individual toilet (UoN & UCB, 2011). In addition, the community toilets available to the other residents are dilapidated, poorly lit, and not connected to the municipal sewer. It was also observed that the sewer lines which do exist are non-functional or drain the sewage directly into the streets, homes, and eventually the rivers (UoN & UCB, 2011). Another significant finding is that only 29% of households in Mathare live within 30 metres of a functioning community ablution block; this means that over 70% of residents have to walk for a distance of more than 30 metres to access a toilet. This finding is significant as most people, especially women and children, may not find it safe to access these facilities at night. This has resulted in open defecation and the use of 'flying toilets'[4] in the settlement (UoN & UCB, 2011). Based on the MPI criteria, we can conclude that the current sanitation situation in Mathare is a strong indicator of poverty in the settlement, and as a result, poverty is a major contributor to urban waterways pollution in Nairobi.

The urbanisation of poverty necessitates discussion of sustainable development, a concept that emerged in the 1980s in response to adverse effects of development on the environment (Cobbinah et al., 2015). The concept of sustainable development was put forward by the Brundtland Commission in its report on the global environment and development in 1987 (Grober, 2007) and popularised during the Rio Earth Summit of 1992 (Redclift, 2005). It was the first global attempt at considering environmental aspects of development from a socio-economic and political perspective (Redclift, 2005). The Brundtland Report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987)

[4] Also referred to as 'wrap and toss', the flying toilet involves defecating in a bag and throwing it away.

Table 1: MPI poverty indicators (Alkire et al., 2012, p. 5)

Dimensions of poverty	Indicator	Deprived if…	Weight
Education	Years of schooling	No household member aged 10 years or older has completed five years of schooling.	1/6
	Child school attendance	Any school-aged child is not attending school up to class 8.	1/6
Health	Child mortality	Any child has died in the family in the five-year period preceding the survey.	1/6
	Nutrition	Any adult aged 70 or younger or any child for whom there is nutritional information is malnourished.	1/6
Living Standard	Electricity	The household has no electricity.	1/18
	Improved sanitation	The household's sanitation facility is not improved (according to MDG guidelines), or it is improved but shared with other households.	1/18
	Improved drinking water	The household does not have access to improved drinking water (according to MDG guidelines) or safe drinking water is equal or more than a 30-minute walk from home, round trip.	1/18
	Flooring	The household has a dirt, sand, dung, or 'other' (unspecified) type of floor. ,	1/18
	Cooking fuel	The household cooks with dung, wood or charcoal.	1/18
	Assets ownership	The household does not own more than one radio, TV, telephone, bike, motorbike, or refrigerator and does not own a car or truck.	1/18

In its wider interpretation by various authors, sustainable development seeks to foster adaptive capabilities and create opportunities to maintain desirable social, economic, and ecological systems (Cobbinah et al., 2015a). It incorporates three main principles which are intricately related – environment, society, and economy – with the objective of achieving a self-sustaining process. It is widely seen as a framework for balancing socio-economic development with environmental conservation. However, there is growing disillusionment in Africa where this outcome has not materialised (Cobbinah et al., 2015a). The urbanisation process in Africa has not been accompanied by sustainable development, as has been the case in most developed countries.

This has led to the argument that the concept of sustainable development does not always work alongside urbanisation (Cobbinah et al., 2015a). Studies conducted in Africa indicate that urban areas are finding it difficult to deal with unplanned and unsustainable development, which has eroded the socio-economic and environmental benefits associated with urbanisation and sustainable development (Cobbinah et al., 2015a). This view is supported by the debates on the urbanisation of poverty which show that Africa's urbanisation has mainly been driven by demographic factors and occurs in the absence of socio-economic and environmental benefits (Cobbinah et al., 2015a; Zhang, 2016). This study therefore focusses on the adverse negative effects of unsustainable urban development which have led to the proliferation of informal settlements and the subsequent degradation of urban waterways in Nairobi city.

In response to the urbanisation challenge in Africa, various United Nations–based organisations have been established to help improve functionality and liveability in the urban environment (Cobbinah et al., 2015a). These sustainable development–based organisations include the United Nations Environmental Programme (UNEP), the United Nations Human Settlement Programme (UN-HABITAT), and the United Nations Development Programme (UNDP). Despite being active since the 1980s, Cobbinah et al. (2015a) observe that these organisations have not yielded any meaningful improvements in the environmental and living conditions of many affected residents, and that Africa continues to face critical urbanisation-related challenges such as unemployment, inadequate water and sanitation facilities, and increased poverty. To address these challenges, UN-HABITAT (2013) asserts that urbanisation and economic growth are inevitable, and when matched with the right policies and governance, its environmental

consequences are manageable. It is therefore important to review current global and Kenyan urbanisation trends in order to understand their implications on urban waterways management.

2.2 Urbanisation trends and projections

In the 1800s, only 2% of world's population was urbanised. This increased to 15% in the early 1900s, followed by a sharp increase after 1950 to 30%. By the year 2007, 54% of world's population was urbanised, and it is projected that by the year 2050 this will increase to 72%, from 3.6 billion to 6.5 billion people (Zhang, 2016). According to population projections by UN-HABITAT (2010b), virtually the whole of the world's population growth over the next 30 years will be concentrated in urban areas.

Africa was predominantly rural in the early 20th century. It is currently experiencing an annual urbanisation rate of 3.3% and is considered the fastest urbanising region in the world (Cobbinah et al., 2015a). Africa's urban population increased from 33 million to 288 million between 1950 and 2000 and is projected to reach 1.3 billion by 2050. This unprecedented urban growth has severely outstripped the capacities of cities to provide basic services such as sanitation (Cohen, 2006; Hope, 1998).

It is estimated that 72% of the urban population in Africa live in informal settlements (Cohen, 2006). Sustained rural to urban migration has increased the population in cities and led to a proliferation of informal settlements, but with no proportionate increase in the provision of infrastructure and services (Cohen, 2006). Africa experienced the highest urbanisation rates in the world between 2006 and 2010 and this is expected to continue up to the year 2025 (UN-HABITAT, 2010b). The urban population in Africa is expected to rise from 40% currently to 56% by 2050 (UNDP, 2015).

As much as urbanisation is associated with positive socio-economic growth, the UNDP (2015) points out that it can present many human challenges, such as pressure on cities' infrastructure including housing, electricity, water, and sanitation. The projected urban expansion in Africa is anticipated to mainly occur in informal settlements, further increasing economic disparities and unsanitary conditions which could lead to an increase in the spread of communicable diseases such as cholera and diarrhoea, particularly among children (UNDP, 2015). These projections can only mean that urban waterways will continue to face an increasing threat of pollution if city

authorities do not address the proliferation of informal settlements next to urban waterways and the sanitation problems they face.

In Kenya, the urbanisation trends have been rapid and mainly characterised by rural-to-urban migration, as is common in most parts of the developing world. Similarly, the poor have been urbanising faster than the rest of the population, leading to an urbanisation of poverty (Zhang, 2016). The population of Kenya was 38.6 million as per the 2009 census (KNBS, 2010). The census also revealed that one out of every three Kenyans lived in urban areas, representing 12.5 million Kenyans or 32% of the total population. Rapid urbanisation trends observed in Kenya over the years have been as a result of natural population growth as well as rural-to-urban migration (Nabutola, 2011).

Population statistics by the KNBS indicated that Nairobi city had a population of 3,138,369 in 2009. The population of Nairobi has experienced dramatic as explained in chapter 1 section 1.3. An estimated 60% of the current population of Nairobi live in informal settlements on less than a sixth of the city's total land area (Nabutola, 2011; UN-HABITAT, 2006). Nairobi is said to have the highest population growth rates in Africa with an estimated 75% of migrants to the city being absorbed by informal settlements (UN-HABITAT, 2006). It is further estimated that the number of informal settlement dwellers will double by 2020. Rapid population growth in Nairobi is seen as a major driver of environmental change as it affects solid waste generation rates, human settlement patterns, and water consumption (UNEP, 2006). In regard to the present study, it is clear that urban waterways face a threat of increased pollution with increasing urbanisation rates in Nairobi. The city's informal settlements therefore represent a significant challenge for the sustainable management of urban waterways.

2.3 Informal settlements in Nairobi

The vulnerability of informal settlements, as discussed in previous sections in this chapter, have presented a significant threat to urban waterways in Nairobi, and it is important to understand their characteristics and dynamics in order to determine the best way adjacent urban waterways can be managed. The history of informal settlements in Kenya dates back to the colonial era when the British colonialists appropriated large tracts of land in Nairobi and its environs but did not make provisions for the accommodation of Africans (UNEP, 2006). This led to the emergence of the first squatter settlements in Kenya. The trend increased after independence

with the Kenyan government's Africanisation policy drawing more people to the city. The government of the day allowed people who could not find formal low-cost housing to build temporary structures provided they were not close to the central business district (UNEP, 2006). It was not until the 1970s that Nairobi experienced an uncontrolled proliferation of informal settlements, mainly as a result of poor urban policies and the inability of government to provide formal low-cost housing, especially for the poor (Githira, 2016; UNEP, 2006).

In addition, the proliferation of informal settlements increased after the 1970s as a result of rapid population growth, the high cost of land, poor urban planning policies, inadequate formal housing, politicisation of urban development, and an increase in urban poverty (Githira, 2016; UNEP, 2006). It is estimated that informal settlements in Nairobi increased from 50 in 1970 to over 133 by 1995 with a proportionate increase of slum residents from 167,000 to 1,886,000 respectively (UNEP, 2006). Figure 10 below shows a map of informal settlements in Nairobi city. By 2011, it was estimated that the total population of Nairobi was 3.36 million; by 2025, it is projected that as many people as the current city population will reside in informal settlements (Githira, 2016). The sheer numbers associated with the growth of informal settlements are a major concern for Nairobi's urban waterways, especially when considering the inadequate sanitation infrastructure available.

Informal settlements in Nairobi are characterised by high population densities, have a history of neglect by public authorities, and are illegally located on public or private land (Karisa, 2010; UNEP, 2006; Wegelin-Schuringa & Kodo, 1997). They lack basic services such as sanitation infrastructure and solid waste collection services due to their perceived illegitimacy due to their illegality in the eyes of the government. They are mainly located in areas unsuitable for residential development, including flood plains, steep slopes, and near hazardous industrial activities (Githira, 2016). Lack of sanitation facilities is considered one of the major problems facing informal settlements in Nairobi city (Karisa, 2010; Wegelin-Schuringa & Kodo, 1997). Of all the characteristics of informal settlements listed above, the most significant ones for this study are inadequate sanitation and solid waste management as well as location along river valleys. The combination of these two factors has increased the vulnerability of urban waterways to pollution and represents the greatest future challenge of urban waterways management.

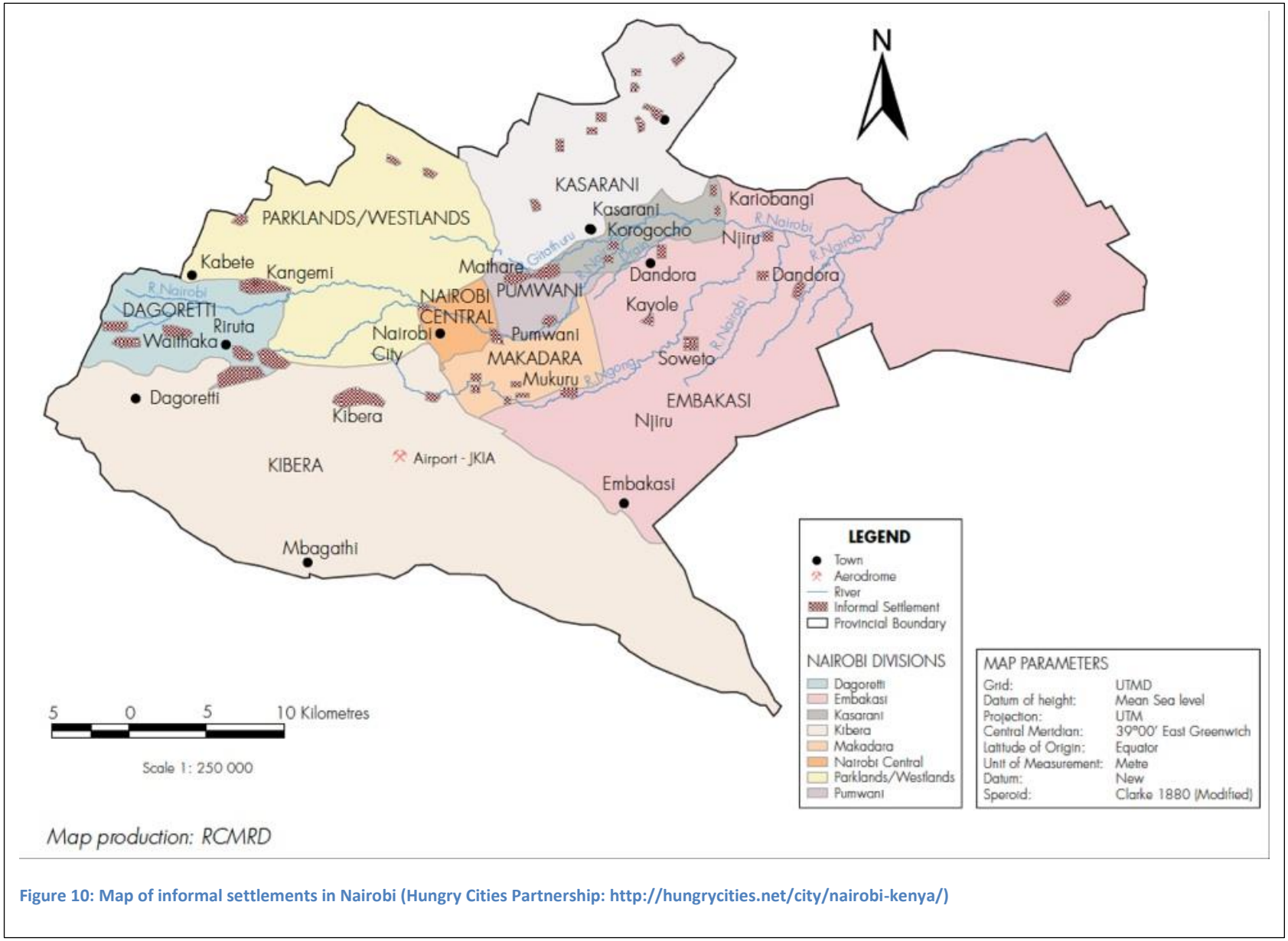


Figure 10: Map of informal settlements in Nairobi (Hungry Cities Partnership: http://hungrycities.net/city/nairobi-kenya/)

Only 48% of the population in Nairobi city has access to the existing sewage system (UNEP, 2006). In the informal settlements, sanitation is meagre, with 94% of the population lacking access to adequate sanitation. In addition, only 10% of population in informal settlements is connected to the municipal sewer; 20% use septic tanks, while the remaining 70% use manually cleaned pit latrines (UNEP, 2006) – this is despite Kenya's Ministry of Health considering pit latrines inadequate as a form of sanitation infrastructure. Sanitation in such settlements usually consists of shared pit latrines, earth drains, and communal water points, with no solid waste disposal systems. In some settlements, one pit latrine may be shared by up to 450 people, leading to quick fill-up, difficulties emptying due to inaccessibility, and the unavailability of spaces to dig new pits (UNEP, 2006).

Inadequate sanitation provision has had negative impacts on the environment, especially on the rivers in which are discharged raw and partially treated sewage as well as solid waste (UNEP, 2006). Studies have shown that for all three rivers in Nairobi, the concentration of coliforms (associated with sewage) substantially increases downstream with little or no dilution effect due to the high rate of discharge of human waste along the river continuum (Musyoki et al., 2013; UNEP, 2006). As a result, there has been an increase in preventable water-related illnesses, accounting for 50% of all reported illnesses countrywide (UNEP, 2006).

The problem of sanitation in informal settlements therefore seems to be at the forefront of urban waterways pollution in Nairobi. It is an issue that seems not to have received much attention from government, especially in regard to the pollution of urban waterways; if anything, inadequate sanitation is only mentioned in passing as intrinsic to informal settlements with no effort to achieve an in-depth understanding or make a connection with the river ecosystems. Yet combined with other factors, such as industrial pollution, this sanitation issue has rendered the Nairobi River Basin the most polluted in the country, as pointed out by Karisa (2010) and UNEP (2006). Sanitation, therefore, becomes a major discussion point in regard to the pollution of urban waterways in Nairobi as it seems to be the major cause of pollution not only from informal settlements but also from the city's sewage treatment plants.

2.4 Sanitation and urban waterways

Sanitation has been defined as the safe management of human excreta and disposal of associated wastewaters (UN-Water, 2008). This definition has been expanded to include environmental

cleanliness, handwashing, and garbage disposal in an attempt to capture the concept of 'total sanitation' (UN-Water, 2008). It is a holistic definition which captures the connectivity of the human system and the environmental (biophysical) system, which includes water resources. Sanitation can therefore be seen as a vital linkage or intervening variable between these two systems where, if adequate, both systems are sustained, but if inadequate, both face serious risks in terms of pollution, outbreak of diseases, and destruction of ecosystems, especially for rivers.

Sanitation is a subject that has often been overlooked, with many people assuming that clean water provision is the main issue – as has been witnessed in most global conventions with no or little mention of sanitation (UN-HABITAT, 2003). It has been argued that most global issues concerned with unsafe water often fail to mention the real culprit, which is "shit and the lack of sanitation" (Jewitt, 2011, p. 608). This statement, in its directness and vulgarity, seeks to break down the taboo surrounding unsafe disposal of human excreta. Unsafe disposal has had adverse effects on the environment and has led to the outbreak of water-borne diseases leading to preventable deaths, especially in the developing countries. The subject of human excreta has been buried in euphemism and avoidance, yet it is an unavoidable daily activity that all humans must engage in (Black & Fawcett, 2010, p. 1). The unsafe disposal of human excreta has led to a global catastrophe associated with diseases and even death, yet discussions focus on water-related disease when most is actually sanitation and hygiene-related (Black & Fawcett, 2010).

Common outcomes associated with inadequate sanitation as highlighted by UN-Water (2008) include pollution of environmental and water resources, social misery, especially for women and elderly, the spread of disease and high child mortality rates, and depressed economic growth. It is clear that inadequate sanitation has adverse effects on various sectors in both the socio-economic and biophysical systems. In regard to the latter, UN-Water (2008) observes that in areas with inadequate sanitation infrastructure, approximately 90% of human excreta ends up in waterways, causing serious pollution. As a result, the sanitation crisis has rightfully been described as "a hidden global scandal constituting an affront to human dignity on a massive scale' (UN-Water, 2008, p. 6).

This statement is indisputable and can be supported by statistics estimating that over 40% of the population in developing countries still depends on a bucket, a bush, the banks of a stream, the back of an alley, and other similar sheltered places to 'go to the toilet' (Black & Fawcett, 2010).

The total number of urban dwellers lacking adequate sanitation provision in the year 2000, globally, was 173 million for water and 403 million for sanitation (UN-HABITAT, 2003). With the current urbanisation trends, the world is fast becoming crowded, and this further complicates the sanitation situation. As a result of inadequate sanitation, it is estimated that 1.5 million children die each year globally due to diarrheal disease (Black & Fawcett, 2010; Jewitt, 2011).

In recognition of the world sanitation crisis, in 2003 the United Nations, through its Millennium Development Goal 7 (MDG 7), made a first attempt at reducing by half the proportion of people without access to safe drinking water and improving the lives of at least 100 million slum dwellers by 2020 through sanitation improvement (UN-HABITAT, 2003). Subsequently, 2008 was proclaimed the International Year of Sanitation, and a United Nations report indicated that between 1990 and 2004, 1.2 billion people had gained access to improved sanitation (Black & Fawcett, 2010). As impressive as the progress seemed, around 2.6 billion people globally still do not have access to improved sanitation (Black & Fawcett, 2010; Jewitt, 2011; UN-Water, 2008). It is also noted that of these 2.6 billion people, 946 million defecate in the open, including behind bushes, in street gutters, and in or around open water bodies such as rivers (WHO, 2016). In addition, MDG 7, to halve the proportion of people without adequate sanitation, was missed by over 700 million people globally. Progress was especially hindered in sub-Saharan Africa and Southern Asia. The failure of MDG 7 has been attributed to unprecedented population growth, especially in urban areas in developing countries, that is not matched with proportionate provision of sanitary facilities (Black & Fawcett, 2010).

Adequate sanitation is often associated with individual households having a reliable 24-hour water supply with internal plumbing and a water closet (WC) toilet connected to a municipal sewer (Jewitt, 2011; UN-HABITAT, 2003). Another common method of dealing with human waste that is also seen as adequate is the ‘drop and store’ approach, mainly associated with ventilated pit latrines for individual households (Jewitt, 2011). The ‘flush and discharge system’ or WC is often viewed as the unquestionable standard, especially for developed countries (Jewitt, 2011). This is because it is convenient, good for public health, and eliminates the hard work of fetching water and getting rid of human waste. As standards are preferred by households only if they are affordable, income levels will to a great extent determine adequacy of water and sanitation provision in most parts of the world (UN-HABITAT, 2003). However, the MDG

criteria used to estimate adequate sanitation provision specifically excludes people who use shared or public toilets as having adequate sanitation; the implication or insinuation of this exclusion is that regions of the world which do not match the norms of the developed world are imagined as failing (Dombroski, 2015).

This has become a significant problem in the push towards provision of adequate sanitation, especially in poor countries. This is because they are under pressure to deal with current sanitation inadequacies by adopting the conventional ideal 'flush and discharge' system because shared toilets are seen to be 'wrong' or 'lacking'. A critique of this position is provided by Dombroski (2015):

> Rather than raising awareness of problematic instances of sanitation (for example, places where water is inaccessible or where open defecation is causing health problems), the current global push for sanitation collates all the diversity of 'other' forms of sanitation and hygiene into one big problem. By no means am I arguing that we should not be concerned about sanitation, hygiene, child health and all the other related issues that the global push for sanitation brings to attention. What I am concerned with is the way that this measurement of lack perpetuates the problem of lumping together a very large percentage of the world's population in a category marked 'other', 'lacking' or 'wrong'. Why are shared toilet facilities classed as 'lacking sanitation'? Is there shame in sharing toilet facilities with others in a compound? Are we all entitled to private toilets and anything else is unacceptable regardless of whether alternatives that maintain a sanitary environment are in place? (Dombroski, 2015, p. 2)

This argument brings to light some critical viewpoints regarding sanitation in most developing countries. Lumping populations of these countries using sanitation methods such as shared toilets as 'wrong' or 'inadequate' misses the point of the fundamental principle of sanitation itself: the safe disposal of human waste. The argument should therefore not be on who is right or wrong but rather on where human waste actually ends up, whether the people are comfortable using these facilities, and whether they are accessible and well maintained. If the objective of sanitation – the safe disposal of human waste – is achieved, then the means through which it was achieved should be deemed adequate if they address the questions I have posed above. Likewise, Dombroski (2015) points out that the concept of sanitation should embrace multiplicity and diversity from different cultures and parts of the world, rather than accepting a preconceived

standard of what sanitation 'ought' to look like and then measuring how far a place is from this standard.

Rather than engage in debates on what constitutes 'right' and 'wrong' approaches to sanitation, specific issues facing different countries should be identified and dealt with on a case-by-case basis considering the underlying factors in each area, such as cultural background, population density, the poverty situation, and governance challenges. These underlying factors are what determine the most suitable sanitation approach to be used at a specific location. For instance, informal settlements are characterised by high population densities, high poverty levels, and insufficient available land for sewer infrastructure or an individual pit latrine for each household. Therefore, taking these underlying factors into account, the best sanitation approach would be provision of easily accessible and well maintained shared community ablution blocks. This is an ideal pragmatic approach, one that Dombroski (2015) refers to as 'starting with what is there' and looking for multiple possible futures. This statement explains the importance of adopting an incremental approach to addressing sanitation problems by firstly using what is already available and gradually improving it in the future.

In Kenya, the sanitation problem has persisted, especially in the informal settlements located in Nairobi. It has also been noted that the provision of individual sanitation facilities is not feasible as a result of high densities and high poverty levels (Schouten & Mathenge, 2010). This is due to the high costs involved in constructing conventional sewer infrastructure as well as the high quantity of water required to run the system efficiently. In addition, the monthly service fee payable to city authorities would be unaffordable for most residents in the settlement. The haphazard development of informal settlements is also another factor that would hinder the development of a sewer system within the settlement (Schouten & Mathenge, 2010). Informal settlements also lack adequate water supply, which is a prerequisite for a conventional sewer system. For instance, in Mathare it is estimated that 90% of residents do not have in-house piped water and have to rely on water points (UoN & UCB, 2011). These factors make it extremely difficult to develop a conventional sewer system reliant on a sustainable water supply, and by extension, to provide separate sanitation facilities for each household in the settlement.

As a result of these factors limiting the provision of individual sanitation facilities in informal settlements, Schouten and Mathenge (2010) have explored the idea of communal sanitation

alternatives. They argue that communal toilets present the most viable options for informal settlement dwellers as they are affordable compared to the conventional 'standard sanitation' options. They also point out that it is important that facilities for communal sanitation be selected based on the circumstances specific to the settlement; this means that one option cannot be universally proposed for all informal settlements in the world. The options available for communal sanitation for informal settlements as discussed by Schouten and Mathenge (2010) include ventilated improved pit latrines (VIP), pour-flush toilets, water closets, and biogas toilets.

The VIP is a hole dug in the ground and lined with concrete to allow for the emptying of excreta. It has a ventilation pipe for eliminating odor and allowing air circulation. It needs regular emptying and is prone to stormwater flooding, which can be a health hazard. The pour-flush latrine is connected to sewer, a pit, or a septic tank. Water is poured manually using a bucket after use to flush the waste down from the toilet bowl. The third option, the water closet, is sometimes available for some informal settlements. It follows the conventional accepted sanitation standards but can be modified to make it more affordable and suitable for informal settlements that have regular water supply. This can be done by having a cheaper simplified sewer system which uses less water and has a flexible network that suits the irregular layout patterns of informal settlements. The biogas toilet is the latest technological innovation for communal sanitation. It is comprised of a shallow pit, a bio digester, and a ventilation pipe. This toilet uses the principle of anaerobic digestion to produce methane gas, with the resultant sludge deposited in a pit or septic tank for emptying. The methane gas produced can be used for lighting, cooking, and heating. These four communal sanitation options may be deemed suitable for particular settlements based on their prevailing local conditions.

Even with these options, authors such as Elinor Ostrom and Schouten and Mathenge have argued that community engagement is a key factor in determining the level of success of an available option. The involvement of the beneficiary communities in the construction of their own facilities not only reduces the cost but also encourages proper use, operation, and maintenance (Schouten & Mathenge, 2010). This is a view that challenges the norm that only government agencies can successfully provide and maintain certain infrastructure such as sewage sanitation or health infrastructure (Ostrom, 1996). In addition, the design process of such infrastructure

projects should consider the preferences of the beneficiaries. Ignoring these preferences may lead to communal sanitation facilities ending up underused, misused, or not used at all (Ostrom, 1996; Schouten & Mathenge, 2010). Considering socio-cultural aspects of a community such as religion, culture, beliefs, and needs also play an important role in improving the sustainability of sanitation programmes (Dombroski, 2015; Schouten & Mathenge, 2010).

A successful example, from Brazil, of community engagement in implementing a sanitation programme is given by Ostrom (1996). This example introduces the concept of coproduction, defined as the process through which inputs used to produce a good or service are contributed by individuals from different organisations (Ostrom, 1996). Therefore, coproduction implies that regular citizens can play an active role in producing public goods and services that are of consequence to them. The Brazilian example of coproduction involves citizen participation in developing their own sanitation infrastructure based on their own preferences, especially in terms of construction and maintenance costs. Excerpts from Ostrom's example are summarised below:

> Most analyses of infrastructure have presumed that the provision of infrastructure is best performed by the public sector (government) due to the technical expertise needed to design effective public works, considerable economies of scale, and legal issues of acquiring rights-of-way. The actual construction of infrastructure has usually been undertaken by public agencies themselves or contracted to private for-profit contractors. The opportunities for illegal side payments in this form of provision and production are substantial. This system has not been successful in providing water and sanitation in developing countries even after decades of assistance by international donor communities.
>
> In the 1980s, a Brazilian engineer, José Carlos de Melo, identified several problems of infrastructure provision in developing countries. Firstly, the centralisation of infrastructure at the national level kept municipalities from access to decision-making responsibilities and resources in their area. Secondly, excessively high engineering standards set in the city were inappropriate for bringing better services to poorer regions. And thirdly, citizens were themselves helpless to do anything about squalid conditions even though they possessed skills and time that could be applied toward solving aspects of problems they faced.
>
> In response to these three challenges, de Melo initiated a reform plan, based on a 'condominial system', combining an innovative approach to the design of engineering works with an active role for citizens. Instead of designing sanitation systems with large cast-iron pipes sunk deep under

> the urban streets at a high per-household cost, he proposed much smaller feeder lines that could run through urban blocks through backyards, front yards, or sidewalks. This design reduced the cost of construction to one-fourth that of conventional designs. The local residents were then involved in digging and maintaining the feeder lines, which were then connected to the main larger trunk lines constructed to regular engineering standards.
>
> A key part of this programme was the activation of local citizens to participate. This was achieved by setting up a series of neighbourhood meetings to discuss the programme overview, opportunities, and costs of the system per structure. More detailed meetings were also held at each housing block to discuss choices residents had to make, cost implications, and maintenance of the system. The overall performance of these condominial systems have varied from project to project. Their levels of success depend on three factors: the organisation of citizens and their fulfilment of promises to undertake collective action, good teamwork within a public agency, and effective coordination between citizens and agencies. (Ostrom, 1996, pp. 1074-1075)

Ostrom also noted that while not all condominial systems have worked, most have been successful and have dramatically increased the availability of cheaper effective sanitation services to the poorest neighbourhoods of Brazilian cities (Ostrom, 1996). Such accounts of communal sanitation options and coproduction provide evidence that the sanitation situation in informal settlements can be addressed using a set of innovative ideas combined with active community engagement as well as alternative technologies that are cheaper and equally effective. It is not a must that sanitation conforms to the universal international standards as prescribed by the MDGs as there are other alternatives that can deal with area-specific problems just as effectively. This presents some hope for the future management of urban waterways in Kenya as informal settlements and their inadequate sanitation represent the greatest threat of pollution.

This chapter has revealed that sanitation provision remains a great challenge in urban areas of developing countries such as Kenya. This is against a background of rapid urbanisation rates and constantly increasing urban populations in cities of developing countries, especially Nairobi in the case of Kenya. This unsustainable urbanisation associated with poverty has led to the formation and proliferation of informal settlements along riparian zones of urban waterways in Nairobi which are inadequately provided with sanitation infrastructure and solid waste

management services. This failing poses the greatest threat of pollution of urban waterways as approximately 90% of poorly disposed human waste will end up in rivers (UN-Water, 2008).

In answering the two research questions posed earlier in this chapter, we can conclude that urban waterways in Nairobi serve as conduits of sewage and solid waste disposal due to inadequate sanitation infrastructure and solid waste management services. This chapter has also revealed that informal settlements in Nairobi are not the only culprit in regard to the pollution of urban waterways. City sewage treatment plants also discharge poorly treated effluent into Nairobi River. Still, the prospects of communal sanitation and sanitation infrastructure coproduction present a glimmer of hope for the future restoration and sustainable management Nairobi's waterways. In this regard, chapter 3 explores different approaches to the management of urban waterways and analyses the current management structure in Kenya.

CHAPTER 3: APPROACHES TO URBAN WATERWAYS MANAGEMENT

Informal settlements that have sprouted along riparian zones in Nairobi present a particularly complex challenge for the protection and conservation of urban waterways. This is because they lack basic sanitation infrastructure and solid waste management services, leading to the heavy pollution of waterways that pass through them. The complex social, economic, and political nature of these settlements further compounds the challenge of urban waterways management and has been an issue that most government institutions have failed to deal with effectively or have simply totally ignored. Over the past three decades, population densities in these settlements have been increasing, leading to increased degradation of waterways, while downstream communities depending on these same waterways have had their main source of water contaminated, with adverse effects on health and reduced water availability. Sustainable management of urban waterways is therefore vital not only for downstream communities but also aquatic ecosystems and urban communities alike.

This chapter discusses sustainable management of urban waterways, showing how they are currently hierarchically managed in Nairobi and discussing alternative management strategies based on active community participation. The chapter addresses objective 5 of this study, which is to review urban waterways management practices with a view to informing sustainable management. I begin by discussing the idea of integrated water resource management, as prescribed by the Global Water Partnership. I then introduce the current management model of urban waterways in Nairobi and restoration and rehabilitation efforts that have been attempted. This will be followed by a discussion of the adaptive cycle as an alternative systems approach to explaining and conceptualising the pollution of urban waterways in Nairobi. Finally, I discuss the practice of 'commoning' as an alternative management option in informal settlements, as opposed to the purely centralised authoritative management strategies of government agencies.

The concepts of adaptive management and commoning are combined to provide an in-depth analysis of how informal settlement residents interact with urban waterways and also factor in the role of management agencies. Commoning and adaptive management represent the use of a non-linear model incorporating different spatial and temporal scales of the urban waterways pollution phenomenon. From this conceptual framework, based on a nested adaptive cycle

(panarchy), we are able to identify the key processes that constitute the urban waterways pollution phenomenon at three different geographic scales – the settlement level, the city-wide scale, and the regional scale encompassing the larger Athi River Basin.

3.1 Integrated Water Resource Management

Integrated water resource management (IWRM) is based on the idea of considering water resources holistically to ensure wider participatory management across all relevant sectors (Giordano & Shah, 2014). The idea was first conceptualised during an international summit on water and the environment held in Dublin in 1992, according to Mitchell (2005). On the other hand, Biswas (2004) argues that the concept had been in existence since the 1950s and was adopted by all members of the United Nations in 1977, in contrast to the Dublin Principles, which were recommendations put forth by water experts that were never approved by any government. This illustrates the arguments and debates on aspects of IWRM ranging from the origin of the concept to its fundamental principles and its practicality in solving the world's water problems. For the sake of understanding what the concept represents, I will focus on the Dublin Conference recommendations, now universally adopted in definitions of IWRM. The recommendations of the Dublin summit were later included in Agenda 21 of the 1992 Rio Earth Summit supporting the principle that water problems cannot be treated in isolation and should be considered in relation to land-use planning issues (Giordano & Shah, 2014; Mitchell, 1990, 2005). IWRM can, therefore, be viewed in three ways, as suggested by Mitchell (1990):

1. IWRM implies systematic consideration of various dimensions of water such as ground and surface water as well as quality and quantity. In this regard, water comprises an ecological system with a number of interdependent components. Management of water in this case is done in regard to the interrelationships, and attention is mainly directed to joint consideration of water supply, wastewater disposal, and quality of water.

2. Water is viewed as not only a system but also a component interacting with other systems. In this case, we address the interaction between water, land, and the environment taking cognizance of the fact that changes in any one component may have effects on the others. Some of the relevant issues dealt with at this level include floodplain management, erosion control, recreational use of water, and non-point water pollution.

3. The third view is broader and approaches water management with reference to the interrelationships between water and social economic development. It is based on the Brundtland Commission's view on the relationship between environment and development and how water is both an opportunity for and barrier against economic development. The main interest on this level is role of water for hydroelectric power (HEP) generation, transportation of goods, and industrial processes.

In addition to the three interpretations highlighted above, the concept of IWRM may be applied to different levels of analysis, including the normative, strategic, and operational levels (Mitchell, 1990). Attention at the normative level is directed to decisions as to 'what ought to be done'; the strategic level is about 'what can be done', while operational level is about 'what will be done' (Mitchell, 1990). The interpretations and levels of IWRM discussed here follow a systems approach of thinking, as will be discussed later in this chapter. The normative level represents the large scale, which could be viewed as the river basin/catchment; the strategic level represents the medium scale and could be viewed as a sub-catchment; and the operational level represents the small scale, which could be viewed as a household or village. Similarly, the three interpretations of IWRM, numbered 1 to 3 above, contain the aspect of scale, with number 1 being the small scale and number 3 the large scale.

The idea of IWRM has sparked heated debates over the years among scholars and professionals as to the practicality of this approach in solving real-world water problems (Giordano & Shah, 2014; Mitchell, 2005). Main criticisms of IWRM have been on interpretation, definition of terms, identification of variables to be considered, and delineation of boundaries in regard to ecosystems management (Biswas, 2004; Mitchell, 2005). Critics have argued that that IWRM is subject to different interpretations and that the terms associated with IWRM are controversial and lack objectivity thus affecting operationalisation of the concept (Biswas, 2004; Mitchell, 2005). Currently, the most universal and widely quoted definition of IWRM was formulated by the the Global Water Partnership (GWP) in 2000, which defined it as "a process which promotes coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2000, p. 22).

Biswas (2004) presents a lucid critique of the above definition of IWRM by posing questions such as what is meant by 'promoting' the concept of IWRM? Who does this? Why and through what process? He also questions what is meant by 'land and related resources'. Another fundamental question posed is on 'maximising': what parameters are to be maximised and who selects the parameters? This question is important since Biswas (2004) states that water professionals came up with these definitions without consulting other relevant professionals in different disciplines such as land-use planning and environmental management. Another question posed is on determining what is meant by 'economic and social welfare' and whether water professionals can maximise these in operational terms. The issue of what is meant by 'equitable' is also raised, asking who decides what is equitable, for whom, and from what perspectives. Sustainability was also highlighted as a vague term in this definition and was questioned as to how it can be defined in operational terms. Lastly, Biswas questions what constitutes 'vital ecosystems' and how to differentiate them from 'non-vital' ones.

What can be concluded from Biswas is that when all the above uncertainties and unknowns are aggregated, the only objective conclusion is that the definition of IWRM is impressive but unuseable and unimplementable in operational terms. The current definition does not provide guidance as to how IWRM can be used to make existing water management more rational, efficient, and equitable (Biswas, 2004). IWRM has therefore emerged as a popular, vague, undefinable, and unimplementable concept which may not be readily applicable in a heterogeneous world with different sociocultural, economic, environmental, and political characteristics (Biswas, 2004). The tragedy of this situation is that the vagueness of a concept increases its popularity since people can continue doing things in the same way while claiming to be following the new paradigm, without any visible changes or improvements in water resource management (Biswas, 2004).

Proponents of IWRM have argued that the concept is not an end in itself but a means, but as Giordano and Shah (2014) point out, when moving from ideas to implementation, IWRM has become an end. This was caused by the requirement that UN signatory countries develop IWRM documents and plans, which only led to a majority of these countries introducing IWRM terminologies in policy documents and not altering actual practice. Developing countries were required to prioritise the development of IWRM with the help of 'supporting agencies' as a

precondition to receiving financial assistance for water related issues (Giordano & Shah, 2014). Supporting agencies mentioned by the UN include development banks such as the World Bank, Asian Development Bank, and African Development Bank. These agencies made the implementation of IWRM core to their water business, thereby "transforming a noble idea into a 'sanctioned discourse' of a means to an end (backed by loan conditionality)" (Allan, 2003, as quoted by (Giordano & Shah, 2014, p. 6). In an attempt to obtain funds for water management, many developing countries such as Tanzania and Ethiopia were forced to abandon their initial focus on key priority water problems in favour of IWRM principles as prescribed by the 'supporting agencies' (Giordano & Shah, 2014).

Another concern is the assumption that integration is desirable without considering its cost. Integration is seen as a costly process which diverts resources from more important tasks in a project (Mitchell, 2005). Critics further argue that many situations are characterised by straightforward problems which could be handled by one organisation without the need for integration. Integration only becomes important in the face of multiple causes, requiring inputs from multiple organisations and participants to complement each other's efforts (Mitchell, 2005). An important issue that has also been raised is the fact that IWRM is seemingly void of politics which in fact are viewed as at the core of all water decisions (Jensen, 2013). It is therefore common to hear activists talk about 'political goodwill', in essence an appeal to those in power to support their initiatives in the matter of water-related issues.

On the other hand, proponents of IWRM have argued that notwithstanding the shortcomings and challenges discussed above, it provides a holistic way of managing water resources based on the view that a broad array of variables and their interrelationships should be examined as a system (Mitchell, 2005). This is because many land-related activities have an effect on water resources in terms of flow and quality. Likewise, water resources may have implications for land-based systems through, for instance, flooding and erosion. This is certainly the case with the urban waterways pollution phenomenon in Nairobi city, where land and water systems are interacting on a daily basis with implications for both systems. An integrated approach is therefore seen as providing one way of addressing dynamic interrelated systems by identifying critical relationships of variables in both systems for better management (Mitchell, 2005).

The concept of IRWM has some shortcomings due to its perceived universality and the assumptions of a homogeneous world (Biswas, 2004; Giordano & Shah, 2014; Mitchell, 2005). The initial proponents of IWRM may have had good intentions, but when the concept was hijacked by international financiers, it turned into a vague, unimplementable, and heavily contested concept (Biswas, 2004; Giordano & Shah, 2014). Moving from the currently global adaptation of IWRM (capital letters) back to the conventional well-meaning 'integrated water resource management' as discussed by Giordano and Shah (2014) represents a perspective that shifts the focus back to solutions to specific problems rather than on universal water-centred approaches. This involves understanding the physical, social, and especially political context of water challenges specific to their locations (Giordano & Shah, 2014). We are referred to the views of Elinor Ostrom and her colleagues, who pointed out that there is no one best system for governing water resources and that many more viable ways exist for resource management than envisioned in much policy literature (Giordano & Shah, 2014). In conclusion, Giordano and Shah (2014) point out that we need to identify water-specific problems first and then work towards finding practical solutions, whether they use IWRM principles or not.

The shortcomings of IWRM have led to the rise of more focussed people-centric approaches such as management of common pool resources (CPRs). Management of CPRs includes 'commoning' as one approach that can be used to address a specific problem in a specific geographical setting taking into consideration the prevalent physical, social, and political dynamics of the area. This concept is discussed in detail later in this chapter, after examining how water resources are generally managed in Kenya and determining whether there is a specific structure for urban waterways management in Nairobi, especially in regard to informal settlements.

3.2 The hierarchical management structure for urban waterways in Nairobi

An analysis of the current water management structure in Kenya reveals that the country has widely adopted the idea of IWRM as proposed by the GWP. There exists no specific structure for the management of urban waterways in Nairobi or generally for rivers in the country. Current water management in Kenya is done under three distinct levels: central government, regional, scale, and county government. Provisions made in various Acts of Parliament promote a generally disjointed system of water management in Kenya as these Acts have established

different government agencies with different mandates and policies in water management. The situation was further compounded by devolution of power in the country which established county governments in 2010. The county governments also claim autonomy in the management of water resources within their areas of jurisdiction. The most notable institutions that I will briefly discuss in this section include the Water Resource Management Authority, the National Environment Management Authority, the Tana and Athi Rivers Development Authority, and agencies within Nairobi City County Government.

3.2.1 The Water Resource Management Authority

The Water Act of 2002 vested all water resources in the state and established the Water Resource Management Authority (WRMA) to oversee water resources management in Kenya. The WRMA is therefore in charge of preparing the national water management strategy and ensuring allocation and the maintenance of water quality (GoK, 2002). The authority is also charged with issuing water permits and determining any charges to be imposed for the use of water resources. More specifically, and in regard to this study, the WRMA has the function of regulating water resource quality and protecting against adverse effects. The WRMA has been given the authority to determine and gazette water catchment areas from which rainwater flows into a watercourse (GoK, 2002). The country therefore has a water management framework based on catchments and sub-catchments as the core units of management.

The WRMA has the authority to formulate catchment management plans following public consultation. The idea of public consultation, according to the Water Act, is the publishing of water management-related notices in the newspapers and on national radio to invite comments from the public. In my view, this is a bureaucratic definition of 'public consultation' which is not people-driven but rather more like the government coming up with a plan and asking people to comment. How can it be ascertained that comments and objections raised are even considered, let alone incorporated in the final plans? In addition, how many affected people are able to access newspapers or even listen to the radio and be in a position to contribute? To make matters worse, the Water Act further provides for arrangements to be made for the general public to obtain copies of water-related documents at 'a reasonable cost'. What is a reasonable cost? Who sets this 'reasonable cost? And why should it not be free access? These questions just go to show how 'public consultation' has been interpreted in manner that seemingly excludes, rather than

includes, general public participation in water resource management. In a nutshell, the process is therefore left solely at the discretion of government officers in terms of deciding how water resources will be managed in the country.

The WRMA has adopted an IWRM approach involving water resource users and stakeholders in water resource management (WRMA, 2013). This has been done through Catchment Area Advisory Committees (CAACs) at the regional level and Water Resource Users Associations (WRUAs) at the local level. CAACs provide advisory services while the WRUAs are directly involved in the implementation of sub-catchment management plans (WRMA, 2013). WRUAs represent a form of people-centred management approach over common pool resources (CPRs) directly involving all water users in a particular sub-catchment in the decision-making process. However, this approach seems to have only been applied in the rural hinterlands where water from the rivers is used for irrigation and domestic purposes.

There is no evidence to suggest that the WRUA concept has been applied in urban areas and Nairobi city in particular. Perhaps this may be due to the complexity of urban dynamics and the fact that there is no specific indigenous community in Nairobi but rather people from all parts of the country pursuing mainly economic interests. Therefore, the sense of community as would be found in rural areas, where people were born and raised pursuing their social, cultural, and collective community interests, is lacking. There is also the fact that urban waterways are not utilised as much within the city for agricultural and domestic purposes, although there is some small-scale subsistence irrigation occurring within the city. In my opinion, the inability of the WRMA to come up with a people-centred approach (similar to WRUAs in rural areas) to managing urban waterways in Nairobi is one of the contributing factors of the persistent degradation. As the authority in charge of water management, the WRMA has no specific strategies for rehabilitating or restoring urban waterways in Nairobi, as per the strategic plan for 2013 (WRMA, 2013). This gives the impression that the organisation is either overwhelmed or non-committal in addressing the complex pollution phenomenon in urban waterways.

However, recently, as a result of public outrage over worsening collective adverse effects on the entire Athi River Basin, the WRMA has been forced to acknowledge and address the issue. In reaction to this pressure, it launched the Athi River Restoration Programme (ARRP) under a theme dubbed “A Clean Athi River: My Life, My Responsibility” (WRMA, 2016). The

programme aims to protect water resources against pollution and also work in collaboration with stakeholders to address sanitation and solid waste management (WRMA, 2016). To achieve this, the programme suggests river clean-up campaigns, wetland restoration, and enhanced programme enforcement. It also proposes the engagement of county governments in matters of sanitation and proper management of solid waste. The initial budget for the programme is estimated at 2.5 billion Kenyan shillings (WRMA, 2016).

The ARRP seems like a noble undertaking, but in my view, it does not address any specific problems in regard to river degradation. The programme contains broad objectives and strategies which might not be implementable due to the wide focus on the entire Athi River catchment covering over 37,750 km^2 in 11 counties, with two being major cities (Nairobi and Mombasa). The proponents of this programme seem to have, assumed homogeneity throughout the Athi River catchment by proposing an umbrella approach in coming up with proposed strategies. This is contrary to the fact that the Athi River Basin comprises different landscapes with different sociocultural, economic, environmental, climatic, and political characteristics whose water problems cannot be solved by an 'umbrella solution'.

In addition, of the estimated budget of 2.5 billion Kenyan shillings, only 100 million seems to be budgeted for actual river clean-up exercises and wetland restoration; the remaining 2.4 billion has been budgeted for activities such as developing sub-catchment plans, developing a corporate social responsibility programme, capacity building for WRUAs, and strengthening the capacities of implementing institutions, among others. This budget is in Appendix A. Therefore, it seems that only 4% of the proposed restoration money will go towards actual concrete outputs. The remaining amount will probably get lost in bureaucratic processes and plans that may never be implemented. With such misplaced budget priorities, I do not expect to see any improvements in water quality within the Athi River Basin any time soon.

In the ARRP, there is no specific mention of urban waterways and the informal settlements dilemma apart from the proposition that the WRMA will somehow engage county governments on sanitation issues and solid waste management. This is a good example of the tragedy of the vagueness of a concept as discussed by Biswas. In the name of following the new paradigm of IWRM, towards integration, budgets are allocated for engaging county governments on sanitation issues but there is no indication what concrete outputs this will yield or what this

engagement entails. So, is this not doing things in the same old way while claiming to be following a new paradigm? Organising expensive meetings with no real agenda or achieveable goals? With such uncertainties, the urban waterways pollution phenomenon in Nairobi can only get worse until more focussed river management and restoration strategies are adopted taking into consideration the specific problems of specific areas within the catchment. Likewise, we cannot have 99% of river restoration funds getting lost in bureaucratic processes under the pretext of capacity building and plan preparation processes; funds must be allocated towards actual implementation of programmes involving activities that directly improve river quality. In my opinion, over 70% of budgetary estimates for the ARRP should go towards concrete and tangible outputs for the actual rivers within this catchment. Until then, it seems the programme shall remain vague and unimplementable with little or no chance of improving water quality within the Athi River Basin.

3.2.2 The National Environment Management Authority

The Environmental Management and Coordination Act of 1999 provides for the establishment of a legal and institutional framework for environmental management in Kenya. It is based on the principle that all citizens are entitled to a clean and healthy environment which includes access to segments of the environment for recreational, educational, health, spiritual, and cultural practices (GoK, 1999). It also provides a basis for legal redress in the High Court of Kenya for citizens who may feel that their entitlements have been contravened. The Act provided for the establishment of the National Environment Management Authority (NEMA) to coordinate environmental management activities in the country with the aim of ensuring rational utilisation of natural resources and environmental protection. It further established the National Environment Action Plan Committee to prepare action plans dealing with all issues concerning natural resources and environmental management in Kenya.

In regard to rivers, the Act states that "no person shall, without prior written approval… deposit any substance in a lake, river or wetland or in, on, or under its bed, if that substance would or is likely to have adverse environmental effects on the river, lake or wetland" (GoK, 1999). It also provides for the protection of river banks against degradation and gives the minister in charge of the environment the power to declare a river bank to be protected if s/he so deems fit. The minister responsible for the environment also has the power to initiate the development of overall

management plans and regulations for rivers and also contingency plans for the prevention and control of all deliberate and accidental discharge of pollutants into the sea, lakes, or rivers. Any person who pollutes aquatic environments including rivers is liable to a fine, imprisonment, or both. Any person found guilty is required to pay for the restoration of the polluted river as well as reparation to any affected third parties. The Act provides guidelines on the discharge of effluent, which includes sewage, industrial and irrigation effluent. Any person or organisation intending to discharge effluent in a watercourse is required to apply for a licence to NEMA and also ensure that effluent is adequately treated before discharge. The Act requires that before issuing any discharge licence, NEMA should consider the water requirements of riparian residents and ecosystems, human settlements, and agricultural schemes that depend on the affected water course.

With all the provisions contained in the Act, one would be tempted to think that urban waterways in Nairobi are adequately protected – yet the current situation couldn't be further from the truth. Over the 17 years that it has been in place, the urban waterways have faced continuing degradation, as documented by Kithiia (2012); Musyoki et al. (2013). The Act seems to concentrate and have very strong views mainly on point source pollution while failing to address complex and dynamic non-point source pollution such as what is happening in the informal settlements. NEMA's wide mandate of dealing with all national environmentally related issues also does not help with identifying and focussing on specific problems such as the polluted urban waterways of Nairobi. NEMA has previously undertaken various pollution-related surveys along the Nairobi River and other rivers in the country and takes credit for dealing with a fraction of the point source pollutants identified in the surveys (NEMA, 2013). However, as the situation on the ground indicates, this may not have had any significant impact in terms of improving water quality in the urban waterways of Nairobi.

NEMA's latest strategic plan for the period 2013–2017 does not contain any clear guidelines on water quality improvement in any specific part of the country (NEMA, 2013). However, NEMA has rolled out an Adopt-a-River programme within the Nairobi River Basin which encourages students, community youth groups, and other interested institutions to adopt a nearby river, monitor pollution, and undertake restoration (NEMA, 2016). This pilot project targets the upper regions of Nairobi city which are not as polluted as the middle and the lower parts and which are

well planned with considerably low population densities comprising mainly high- and middle-income residential settlements. The target area of this project is also adequately served with sanitation infrastructure and solid waste management facilities as compared to the other parts of the city. This questions the rationality of using such an area as a pilot study instead of focussing on the areas where the pollution phenomenon is real and raw in the literal sense. Therefore, without going further into the details of this project, it is highly unlikely that any meaningful lessons from this part of the city could be learnt or replicated in more complex areas such as informal settlements which face dire conditions.

3.2.3 The Tana and Athi Rivers Development Authority

Urban waterways in Nairobi city are generally part of the Athi River catchment, which falls under the jurisdiction of the Tana and Athi Rivers Development Authority (TARDA). The TARDA Act established this regional authority in 1974 to advice on the institution and coordination of development projects in the area of the Tana and Athi River Basins. TARDA's functions include the development and exploitation of water resources, especially in regard to hydroelectric power generation, irrigation, water apportionment, and abstraction within the Tana and Athi River Basins (GoK, 1974). Though the establishing Act does not mention anything about conservation, TARDA has been engaged in conservation efforts with one of its key strategies for the period 2014–2018 being river protection for enhanced water quality and quantity (TARDA, 2014). River conservation efforts carried out by TARDA have tended to be focussed outside urban areas and especially in the locality of projects implemented by the organisation such as the Masinga Dam. Previous river conservation efforts mentioned in TARDA's strategic plan 2014-2018 have included check-dam construction, sediment management, promotion of tree planting and supporting high-value tree nurseries, riparian zone protection, and building community capacity to initiate and engage in conservation initiatives (TARDA, 2014).

There is no evidence to suggest that TARDA has ever been involved in the conservation of Nairobi's urban waterways that form part of the Athi River upper catchment. The strategic objective of protecting and conserving rivers within TARDA's jurisdiction, as set out in TARDA's strategic plan, may also be far-fetched as there are no clear guidelines how this will be done and on specifically which rivers, streams, and tributaries. Therefore, TARDA represents an

institution which has regional jurisdiction over the entire Athi River Basin but has done nothing to address the urban waterways pollution problem in Nairobi.

3.2.4 The Nairobi City County Government

The Nairobi City County Government (NCCG) is in charge of all city-related management issues ranging from planning, service provision, infrastructure development and maintenance, collection of levies, and environmental conservation. This is in accordance with the County Governments Act of 2012 which gives effect to chapter 11 of the Kenya's constitution, which provides for county governments' powers, functions, and responsibilities to deliver services and for connected purposes (GoK, 2012). In regard to urban waterways management in Nairobi, environmental issues are dealt with by the Department of Environment while sanitation issues fall under the Nairobi City Water and Sewerage Company (NCWSC).

The county annual development plan (2017–2018) for Nairobi city has identified water resource conservation as a key strategy and has proposed restoration of the Nairobi River. To achieve this, the plan proposes waste removal from rivers, tree planting along riparian zones, and the development of policy documents. However, the plan does not give guidelines on how communities will be involved in this process. The activities also seem highly generalised and are not specific to any area or addressing any specific identified problem. For instance, the plan does not outline how pollution will be dealt with in the informal settlements or industrial areas but instead is limited to general prescriptions.

The NCCG credits itself for removing 16 tonnes of solid waste from the rivers, blocking 10 illegal discharge points, and restoring a 6-km stretch of riparian reserve in 2016 (NCCG, 2016). The county government also plans to extend the existing sewer system by 5 km and connect over 500 homes. The plan also has provisions for improving solid waste management by purchasing refuse trucks and improving the major existing dumping site in Nairobi (NCCG, 2016). These efforts are commendable as they would indirectly help solve the urban waterways pollution issue. However, the plan does not give details as to whether the new sewer connections will benefit informal settlements and how the project will be implemented given the sensitive and complex nature of these settlements.

The NWCSC is in the process of implementing a sanitation project for selected informal settlements in Nairobi (NCWSC, 2016). This is an output-based aid project partially financed by the World Bank with the remaining funds coming from a commercial loan obtained by the NCWSC. The project seeks to provide "reliable, affordable and sustainable basic sanitation and water services to the poor" (NCWSC, 2016). The outputs of the project include water supply and sewer connections and the associated internal plumbing, including toilets, handwashing basins, and storage tanks as necessary, to low-income households. The NCWSC will charge the targeted beneficiaries a uniform connection fee and an additional capital cost recovery fee over a period of five years to repay the loan. In addition, consumers will also be expected to pay a monthly fee for water and sewerage services. Considering that these are low-income settlements, there is no guarantee that residents will chose to connect to the sewer lines given the associated connection costs and subsequent monthly payments. Another problem that arises from this ambitious project is the fact the city sewage treatment plants currently do not have the capacity to treat current volumes of wastewater generated due to sustained population increase over the years (Musyoki et al., 2013). Increasing sewer connections within the city without expanding the sewage treatment plant infrastructure will serve no purpose other than transferring river pollution downstream after discharge from these treatment plants.

The current water resource management structure in Kenya evinces a hierarchical, authoritative, centralised approach incorporating different parallel activities by different agencies with no specific targets for urban waterways in Nairobi. The attempts of these agencies to deal with the degradation of waterways using a 'comprehensive' and hierarchical top-down approach has only led to the formulation of grandiose project proposals which may be unsuitable and unimplementable due to vague objectives and the bureaucratic nature of both the central and county government structures. Some of the proposed projects such as sewer provision to informal settlements by NCWSC have failed to consider poverty levels assuming that the subsidized proposed rates will be affordable to informal settlement dwellers. These agencies have also failed to come up with a framework for genuinely involving the urban communities and other affected stakeholders in the planning and implementation process. Thus urban communities are not able to take ownership of these projects, leading to their collapse. Some of these agencies that have jurisdiction over Nairobi's waterways have failed to respond in any way to the pollution problem, with only broad regional objectives in their plans.

An understanding of this management approach, as has been discussed in this section, is important in helping conceptualise the urban waterways pollution phenomenon in Nairobi. The hierarchical approach adopted in water resource management in Kenya has not been successful, as evidenced by continuing pollution trends. Rather than viewing the management of urban waterways as a centralised hierarchy, I introduce a systems approach which provides an ideal platform for analysing sustainability issues relating to Nairobi's waterways. The systems approach examines all aspects of urban waterways pollution at all scales from the household/settlement scale to the city scale and further to the catchment scale. Management strategies are, therefore, also designed at all scales, thus involving all actors including the urban communities, government agencies, and other stakeholders. As identified in this section, the current management structure has only concentrated on the city and wider catchment scales with little or no emphasis on the local scale (settlement and household levels). This has only led to highly generalised policy statements and grandiose plans which remain unimplementable and unsustainable due to the exclusion of local communities and other stakeholders at the local scale.

The hierarchical approach to the management of urban waterways in Kenya becomes problematic due to minimal community involvement leading to a lack of project ownership, the centralised approach leading to poor management and loss of funds through bureaucratic processes, and the different agencies established creating a disjointed rather than a concerted, focussed approach in dealing with urban waterways pollution (Moraa, Otieno, & Salim, 2012). There is therefore a strong need to adopt a systems approach of thinking in regard to urban waterways management in Nairobi. The systems approach recognises that there are potentially many connections in a system which are not necessary top-down but may also be bottom-up. It also emphasises the importance of urban communities and other local stakeholders in the sustainable management of urban waterways in Nairobi.

3.3 Non-hierarchical (systems) approaches to the management of urban waterways

The shortcomings of hierarchical approaches to the management of water resources as discussed in the previous chapter necessitate the need for viewing the management of urban waterways from a systems perspective. I have chosen the concept of adaptive cycles and the panarchy as a systems way of analysing the urban waterways pollution phenomenon in Nairobi. This section

attempts to discuss the usefulness of the panarchy theory in explaining Nairobi's urban waterways pollution phenomenon. To understand what a panarchy framework represents, we must first understand the adaptive cycle – the basic unit within a panarchy framework.

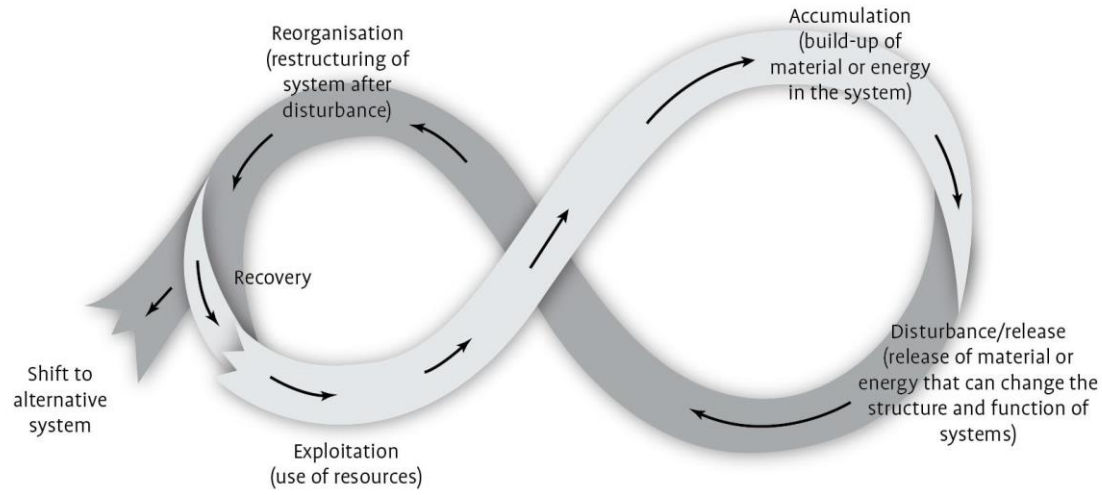
3.3.1 Adaptive cycle

An adaptive cycle represents the continuous interaction between living and non-living elements of a system within a particular domain of scale and period, capturing their development, growth and decay (Allen, Angeler, Garmestani, Gunderson, & Holling, 2014). The interaction between urban waterways and urban land uses such as informal settlements constitutes a system which could be represented as an adaptive cycle. The living elements in this system are the waterways – ecosystems supporting both aquatic and terrestrial life – and the non-living elements include human activities such as informal settlements, sewage treatment plants, and industries. The framework of the adaptive cycle provides a platform for sustainability analysis as it identifies thresholds for system maintenance as well as management interventions to maintain or restore the functions of a system. Thresholds may be viewed as the minimum standards required, for instance, to prevent degradation of waterways. In regard to this study, thresholds may include level of sanitation infrastructure provided, treatment standards for industrial effluent and sewage, provisions for functional riparian zones, level of monitoring and enforcement, and level of community engagement in management. An adaptive cycle has four phases (Holling & Gunderson, 2002), as explained below and shown in figure 11;

- Exploitation phase (r) – use of resources such as land and water
- Accumulation phase (K) – build-up of material or energy in the system as a result of exploitation
- Release/disturbance phase (Ω) – disturbance in the system as a result of accumulation causing release of material or energy and changing the structure and function of the system
- Reorganisation phase (α) – restructuring of the system after disturbance

The exploitation and accumulation phases of an adaptive cycle constitute the front loop. In regard to this study, this loop may be thought to depict increasing urbanisation trends characterised by land use intensification. Holling & Gunderson (2002) observe that the exploitation phase starts with slow growth and proceeds to rapid growth towards the

accumulation phase, eventually reaching a peak which can be viewed as the carrying capacity of a system. For instance, with rapid urbanisation and land use intensification, pressure grows on natural resources such as urban waterways, and when development is not controlled, the carrying capacity of waterways is exceeded, leading to degradation. Carrying capacity may be seen as corresponding to environmental limits brought about by human activities (Seidl & Tisdell, 1999). The proliferation of informal settlements in Nairobi without provision of sanitation infrastructure, and the resultant discharge of raw sewage, could be seen as one means by which the carrying capacity of urban waterways is exceeded. Conventional management of natural resources occurs at the exploitation and accumulation phases of an adaptive cycle (Holling & Gunderson, 2002). This would ideally entail controlling urban development, providing adequate infrastructure and services, and having a strong framework for urban waterways protection.



Source: Adapted from Gunderson and Holling 2002

Figure 11: Phases of an adaptive cycle

The disturbance and reorganisation phases of an adaptive cycle constitute the back loop. The disturbance phase is seen to represent rapid transformation as a result of accumulation of negative energy and materials (Holling & Gunderson, 2002), which in this case study are the pollutants from urban land use activities. At the disturbance phase, pollution thresholds for urban waterways are exceeded, leading to destruction of aquatic ecosystems and making the water non-potable. After disturbance, the system moves on to the reorganisation phase, which presents an opportunity for system renewal (Holling & Gunderson, 2002). For our case study, this could entail devising conservation and restoration measures specifically for the waterways and also managing urban land uses to prevent their further pollution. The reorganisation phase also presents an opportunity to incorporate social objectives (Holling & Gunderson, 2002), which in our case could entail creating a value system for urban waterways to serve as a guiding principle for urban communities to protect them.

The adaptive cycle framework is intrinsically linked to resilience, which is the capacity of a system to absorb shock and retain its core functions and structure – the opposite of which is vulnerability (Allen et al., 2014; Jenkins, 2015). Resilience also refers to the adaptive capacity of a system (Holling, 2001). Resilience determines how vulnerable a system is to unexpected disturbance. For urban waterways in Nairobi, we note that resilience has been decreasing over the years, with intensification of urban land uses and disproportionate provision of sanitation infrastructure making them vulnerable to degradation. Other key properties of an adaptive cycle are connectedness and the potential for resources, as shown in figure 12 below.

Potential refers to natural and social capital, or in other words, the range of accumulated resources such as knowledge, technology, and skills that are available for change in the system (Daedlow, Beckmann, & Arlinghaus, 2011; Gunderson & Holling, 2002). Of importance to this study is the social or cultural potential, which can be represented by the character of accumulated networks and relationships such as trust among people and between people and governance institutions (Holling & Gunderson, 2002). Potential sets the limits for what is possible and determines the number of alternative options for the future (Holling, 2001). In an adaptive cycle, potential increases in the reorganisation and conservation phases, as shown in figure 12 above. Connectedness refers to the degree of internal control that a system exerts over external variability (Holling & Gunderson, 2002). In a more practical sense, and especially in regard to

this study, it could be viewed as the intensity of control by direct human activity since the urban waterways have little or no degree of self-regulation in the face of human-induced variabilities.

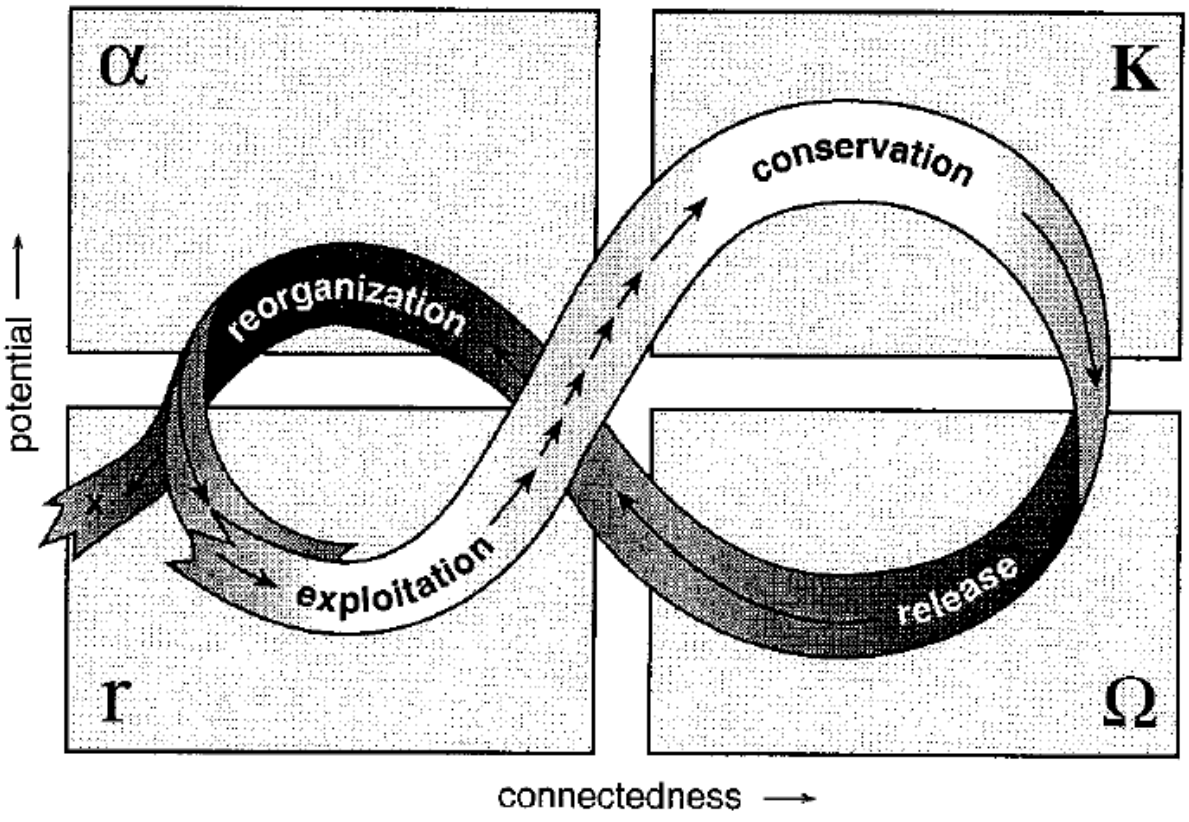


Figure 12: Key properties of an adaptive cycle (C S Holling & Gunderson, 2002, p. 34)

The urban waterway as an aquatic ecosystem in a changing urban land use landscape will highly depend on the intensity of conservation measures by residents, businesses, and relevant agencies. In the absence of human care and responsibility the waterways face continued degradation, but with positive interventions, sustainable management is achievable. Connectedness increases in the accumulation (K) and disturbance (Ω) phases of the adaptive cycle, as shown in figure 12 above.

3.3.2 Panarchy/nested adaptive cycle

A nested adaptive cycle, also referred to as a panarchy, is a set of linked adaptive cycles operating at different spatial and time scales (Allen et al., 2014; Jenkins, 2015). Panarchy

provides a perspective for understanding ecosystems, linked social-ecological systems, and governance (Holling, Gunderson, & Peterson, 2002). Figure 13 below shows a typical panarchy. Panarchy provides a conceptual model that describes ways in which complex systems of humans and nature are organised and structured across spatial-temporal scales (Allen et al., 2014). This model is relevant as a means of representing urban waterways pollution as a linked social-ecological process with complex governance challenges. Panarchy is viewed as different from traditional envisioned hierarchies as control is not just exerted by larger-scale top-down processes but also from small-scale bottom-up processes, thus emphasising cross-scale linkages where processes at one scale affect those at other scales (Allen et al., 2014). An example of a small-scale process affecting a large-scale one is where, in a catchment consisting of rivers and a receiving lake, if nitrate leeching is controlled at the farm level (small-scale), this could improve general water quality within the entire catchment and that of the receiving lake (large scale).

Nested adaptive cycles therefore provide a basis for defining sustainable management as "the maintenance of the structure, function and relationships in the adaptive cycles across different time and geographical scales" (Jenkins, 2015, p. 40). This is a technical definition that fits well within a panarchy framework, not only defining sustainability of water resource use but also integrating urban land uses into the framework. However, a more generic definition of sustainable water resource management, similar in meaning to the above definition, is "water resource systems designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental, and hydrological integrity." (Loucks, 2000, p. 8). Sustainable management is important to this study in regard to objective 5, of this study which is to review urban waterways management practices with a view to informing sustainable management. I have adopted the definition by Jenkins (2015) specifically for discussing the panarchy framework as it captures the entirety of the urban waterways pollution phenomenon occurring at different geographical scales and affecting different users in various ways. The impact of human activities on the waterways within the Nairobi metropolitan region affects downstream users in a wider geographical region. Therefore, sustainable management of urban waterways would entail maintaining the integrity of the waterways to serve their ecological functions and also fulfil the needs of all users within and outside the city – be they recreational or consumptive.

Panarchy provides an ideal systems approach to analysing sustainability issues around urban waterways in Nairobi. Of the many potential connections between adaptive cycles in a panarchy, Holling (2001) observes that of importance for sustainability analysis are the revolt and remembrance connections, as shown in figure 13 below. A system revolts when a level in a panarchy enters its disturbance (Ω) phase of creative destruction; the collapse cascades into the subsequent level by triggering a crisis, especially if the slower level is at the accumulation (K) phase (Holling, 2001). This is because at the accumulation (K) phase, resilience is low, making that particular level vulnerable (Holling et al., 2002). In the case of urban waterways degradation, this can be seen in the transfer of pollutants from the smaller settlement scale to the subsequent larger city scale through a revolt link. Revolt is seen as a process where fast and small processes overwhelm slow and large ones in subsequent higher scales, particularly if those levels have also accumulated vulnerabilities and rigidities (Holling, 2001).

The "remember" arrow shown in figure 13 below presents opportunities or constraints for renewal by drawing on the potential that has been accumulated and stored at a larger, slower scale (Holling, 2001). The remember connection is seen as drawing on the accumulated wisdom and experiences of maturity in large and slower scales, transferring this to the reorganisation (α) phase of the subsequent lower, smaller, faster scales (Holling, 2001). In the urban waterways pollution phenomenon, it could be seen as transfer of accumulated knowledge and wisdom on sustainable river management (from areas outside the city) from the larger, slower scale to the reorganisation (α) phase of smaller, faster scales. I would also like to imagine that it represents transfer of capital (funds) from the national and regional scales to the local scale through budgetary allocations. The opposite could be true in regard to constraints where there is no accumulated wisdom or experience at the larger scale, leading to transfer of ignorance, mediocrity, and incompetence to subsequent lower scales at the reorganisation phase, thus making the entire panarchy unsustainable. Poor governance characterized by bureaucracy and crruption could be seen as another negative transfer of the "remember" arrow leading to loss of funds from the higher national and county government scales meant to enhance resource management at the local level.

A nested adaptive cycle provides a sustainability framework for natural resource management highlighting the interaction of socio-economic and biophysical systems (Holling et al., 2002).

Sustainability depends on interactions among internal and external factors (Holling, 2001). Internal factors may be social, political, economic, or ecological; external factors may include foreign debt, structural poverty, global environmental problems, and socio-political-economic conflicts. These internal and external factors fit well in the urban waterways pollution phenomenon, capturing the complex socio-economic and political intrigues which face informal settlements thereby leading to adverse effects on the urban waterways ecological system. Adopting the view of Holling et al. (2002), these indicators of sustainability suggest that complexity of living systems of people and nature emerges not from the random association of a large number of interacting factors but rather from a smaller number of controlling processes. Examples of global environmental change signal that the stresses on the planet have reached new levels due to the intensity and scale of human activities. This is the case with degradation of urban waterways, which starts at a very small scale (household/settlement and stream/tributary) and escalates into a large geographical region consisting of many rivers/tributaries and millions of people.

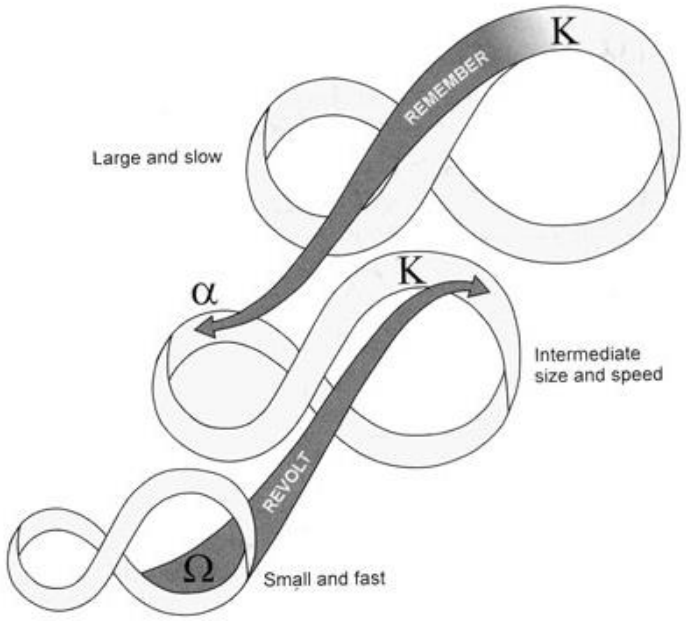


Figure 13: A typical panarchy framework (Holling, Gunderson, & Peterson, 2002)

For sustainability analysis of the urban waterways pollution phenomenon, priority is given to critical variables that create greatest vulnerability within an adaptive cycle and among linkages between the different spatial-temporal scales (critical variables in this case include the minimum water quality standards for domestic use and ecological processes). This is with the aim of ensuring that management interventions keep the critical variables within resilience thresholds and that linkages between different scales are maintained, thus providing an operational basis for sustainability. System response in regard to urban waterways in Nairobi could therefore manifest as either recovery of original system (i.e. sustainable) or change to an alternative state/degradation (i.e. unsustainable). Unfortunately, the latter scenario has persisted for decades. Nairobi's waterways pollution phenomenon as a panarchy is discussed in the results section of this thesis where I present a conceptual model based on nested adaptive cycles. The panarchy framework provides a different, non-hierarchical approach to understanding and conceptualising the management of urban waterways, with a strong emphasis on sustainability issues, in contrast to the IWRM hierarchical framework.

3.4 Commoning Nairobi's waterways

Common pool resources (CPRs) are collective resources over which no one has private property rights or exclusive control, such as natural resources comprising land, water, forests, and fisheries (Bollier, 2014; Singh, 1994). The definition of CPRs, or 'commons', as they are commonly referred to, has been taken further by Bollier and defined as paradigms that combine a distinct community with a set of social practices, values, and norms that are used to manage a resource (Bollier, 2014). This view is shared by Gibson-Graham et al. (2013), who define a commons as "a property, a practice, or a knowledge that is shared by a community" (Gibson-Graham et al., 2013, p. 130). Currently, this definition of commons has been expanded by Bollier (2014)to include not only natural resources but also cultural commons such as language, social commons such as political systems, and knowledge commons such as indigenous ecological knowledge. For the purposes of this study, I will be concentrating on urban waterways as natural resource commons. More often than not, 'commons' are perceived as free for all to use, which can lead to overexploitation and degradation in the absence of effective management (Ostrom, 2015). Commons are also seen as dynamic, constantly being made and re-made and maintained or degraded (Gibson-Graham et al., 2013), a statement that holds true for the urban waterways in Nairobi, only that they are more often degraded than maintained. It is rightfully observed that

most commons that are useful come to our attention only when they are degraded (Gibson-Graham et al., 2013); such is the case with urban waterways in Nairobi. Gibson-Graham et al. (2013) observe that there is no commons without a community, just as there is no community without a commons.

3.4.1 The fallacy of Hardin's 'tragedy of the commons'

For thousands of years communities have managed natural resources collectively for their own benefits while maintaining the ecological integrity of natural systems (Gibson-Graham et al., 2013; Ostrom, 2015). For example, the Aboriginal people of Australia had nurtured natural habitats for tens of thousands of years using the customary practice of fire-stick farming (Gibson-Graham et al., 2013). The practice entailed the lighting of small-scale fires to replenish native vegetation and manage animal populations. However, after colonisation, the Aboriginal people were forced off their traditional lands to live in government settlements, and without their traditional management practices, the land became vulnerable to invasive exotic weeds and feral animals (Gibson-Graham et al., 2013). After, in the early 1970s, the government granted Aboriginal people legal rights to their customary land, they moved back and resumed fire-stick burning. Professionals and scientists took notice of how it replenished vulnerable landscapes and have now officially adopted it as a legitimate land management practice. The practice has brought scientists and Aboriginal people together and has provided employment opportunities for indigenous people who act as rangers to conduct controlled fires for land management purposes. This Australian example illustrates how commoning is not a new paradigm but rather a rediscovery or a readoption of traditional community-based management of natural resources in modern times. It is the way traditional communities collectively managed natural resources in the pre-modernisation and pre-industrial era for thousands of years. In some sense, it could be viewed as 'going back to our roots'.

The idea of the commons was popularised, in a rather unorthodox way, in 1968 by Garrett Hardin in his article 'The Tragedy of the Commons' (Bollier, 2014; Gibson-Graham et al., 2013). Hardin argued that environmental degradation was inevitable whenever many individuals shared the use of a scarce common resource (Hardin, 1968). He used the example of a shared pasture land where each herder wanted to increase their cattle for maximum returns, eventually leading to overgrazing. Hardin's premise was based on the assumption that people act in their

own self-interest without regard for the public good and inadvertently created the misconception that the loss of the commons is inevitable (Gibson-Graham et al., 2013). In order to avert this 'tragedy of the commons', Hardin proposed state or market solutions as opposed to having communities manage the commons (Hardin, 1968). Hardin's model was used to legitimise the use of coercive force or a 'Leviathan' approach in managing natural resources in what he viewed as 'an overcrowding world'. This led to the recommendation that central governments must control most natural resources, a recommendation that has been adopted widely in most developing countries, including Kenya (Ostrom, 2015).

However, scholars such as Ostrom (2015) have disputed these presumptions of the inevitable destruction of commons left in the hands of communities and pointed out that commons have existed for thousands of years without collapse (Lohmann, 2016). These commons have been maintained and managed by communities using a set of rules and norms (Ostrom, 2015). Gibson-Graham et al. (2013) observe that the tragedy occurs only when there are no rules or protocol to manage the commons. Critiques of Hardin's model led to him revising his original paper in a statement he made in 1998 pointing out that he had omitted a key objective and that the tragedy which he had referred to in 1968 was of 'unmanaged' commons (Gibson-Graham et al., 2013). This revision has been criticised as an oxymoron by , who pointed out that the term 'commons' in itself refers to a communally managed resource.

The misconceived presumptions and recommendations of Hardin's model, notwithstanding the later revision to include the word 'unmanaged', have stuck and are evident even in the management structure of urban waterways in Nairobi, as discussed earlier in this chapter. The recommendation to adopt Hardin's model to use coercive force may be misguided, and this is captured by Ostrom (2015), who points out that policy prescriptions for natural resource management have relied on this model but have achieved little more than a metaphorical use of it. Many authors such as Bollier (2014), Gibson-Graham et al. (2013), and Lohmann (2016) agree with this view, and indeed, it is an accurate representation of the urban waterways pollution management dilemma in Nairobi. Even with a strong elaborate government structure of laws, agencies, and policies, pollution has persisted unabated.

As discussed earlier in this chapter, there are various central government agencies and policies addressing the management of water resources in Kenya, and yet the condition of urban

waterways seems not to have improved considerably. In 2008, the government collaborated on a programme to rehabilitate the Nairobi River Basin in partnership with the United Nations Environmental Programme (UNEP), United Nations Development Programme (UNDP), and African Development Bank (AFDB) (UNEP, 2017). The programme was known as the Nairobi River Basin Rehabilitation Programme. The only notable achievement of the programme, as yet, has been the rehabilitation of a two-kilometre stretch of a section of the Nairobi River which lies in the upper part of the city mainly characterised by low population densities and adequate infrastructure provision. Some of the strategies proposed by the programme included relocating informal settlements, stopping illegal discharges, installing and repairing sewage infrastructure, developing a masterplan for economic utilisation of riparian zones, and landscaping and beautification of riparian zones (UNEP, 2017).

This programme seems to have fundamentally failed and nine years down the line, the urban waterways are still experiencing massive degradation. This in itself represents a classical failure of attempting to apply the principles of IWRM (as prescribed by the GWP) and Hardin's model of state management to solve a complex urban waterways pollution problem. The programme failed to provide for a role for urban communities in rehabilitation and even went as far as recommending the relocation of informal settlements as well as the commercialisation of riparian zones. The premises of this programme were clearly based on Hardin's recommendations of a purely market- or state-driven management model for the commons. We can also clearly see the presence of what the United Nations termed as 'supporting agencies' in the form of the AFDB, which, as mentioned earlier, made the creation of IWRM core to their water business model. Even after the failure of this programme, the government is in the process of launching a similar project, the Athi River Restoration Programme, as discussed earlier in this chapter.

Having contextualised the failure of management models for the commons based on Hardin's recommendations of a state- or market-driven approach and the GWP's prescription of IWRM in Nairobi, I explore commoning as an alternative management approach. Planning at the local level and involving urban communities in the management of urban waterways seems to be the missing link and the reason why the pollution problem has persisted over the years.

3.4.2 Reinvention of the commons

> "Many commons have flourished for hundreds of years, even in periods of drought or crisis. Their success can be traced to a community's ability to develop its own flexible revolving rules for stewardship, oversight of access and usage, and effective punishment for rule breakers."
>
> (Bollier, 2014, p. 24)

Having undergone that tragic period of the tyranny of the 'tragedy of the commons', scholars such as Ostrom, Bollier, and Gibson-Graham et al have presented strong arguments for rediscovering the commons. Reinvention of the commons entails acknowledging the vital role that communities play in determining the use and distribution of benefits accrued from commons. This approach demonstrates the failure of Hardin's recommendations for a purely state- or market-based management approach of commons, as evidenced in the management structure of waterways in Kenya. Bollier (2014) gives an example of how waterways have been managed as commons in New Mexico since the 1600s. These community-based waterways are known as *acequias* and the native Hispanic-Americans have aligned their usage with ecological limits. In addition, although *acequias* have been sanctioned by New Mexico state law, it is the community that manages and protects the water supply with all *acequia* members participating in maintenance activities such as the annual cleaning of water ditches. This model of management has succeeded in meeting the needs of the people while conserving water and soil and protecting animal and plant habitats. It stands in contrast with other nearby towns in New Mexico that have been faced with unchecked suburban development and increased water shortages (Bollier, 2014).

Therefore, reinvention of the commons can be seen simply as 'going back to our roots', embracing the spirit of community stewardship in caring for and managing natural resources just as our ancestors did thousands of years ago. Following the successful reinvention of the commons, Gibson-Graham et al. (2013) point out that for a resource to qualify as a 'commons', it must meet the following conditions:

1. Access must be shared and wide
2. Use must be negotiated by a community
3. Benefits must be distributed to the community and beyond
4. Care must be performed by community members
5. Responsibility must be assumed by community members

At first glance, some of the above conditions may seem limiting in regard to classifying urban waterways as commons due to the complex nature of the urban landscape as compared to more rural areas with less industrial and urban development and low population densities. This is because waterways outside the city will ideally be used for agricultural purposes and domestic consumption, whereas in the city they are mainly used for industrial purposes, recreation, and disposal of waste. It therefore seems difficult to apply the second and third of these conditions in regard to waterways in urban informal settlements because in those settlements there are no perceived uses of the waterways apart from the discharging of waste, and there are also currently no perceived benefits which could be shared by settlement residents.

However, Bollier (2014) points out that there is no natural logical classification scheme for commons and suggests that it is easier to simply recognize general clusters of commons that represent certain general charcteristics. In this regard, a critical analysis incorporating a broader conception of the commons reveals that urban waterways can indeed be classified as commons falling under the category of subsistence commons comprising natural resources viewed as gifts of nature (Bollier, 2014). In classifying commons, we also acknowledge the interconnectedness of some commons such as waterways; there are many communities along the river continuum that share the same commons, including urban communities. As much as they may not seem very useful to urban communities, downstream communities rely on waterways flowing through the city for their irrigation and consumption needs. It could also be assumed that if urban waterways were not as polluted as they are now, then urban communities – including informal settlement residents –could also accrue more benefits and uses, such as recreation, urban agriculture irrigation, and consumption. It is therefore possible to apply the above conditions by Gibson-Graham et al. (2013) and Bollier (2014) to qualify urban waterways in Nairobi as commons.

The criteria described above by Gibson-Graham et al. (2013) can be applied towards the commoning of urban waterways in Nairobi. Commoning is defined as the ongoing production and reproduction of the commons and is seen as vital in building community economies and enhancing sustainable management of natural resources such as urban waterways (Gibson-Graham et al., 2013). The process of commoning involves claiming a resource for a collective community or communities and establishing protocols for management (Bollier, 2014; Gibson-

Graham et al., 2013). In the case of urban waterways in Nairobi, we note that the resource is interconnected and shared by different communities throughout the wider catchment beyond the city boundaries. Commoning places strong emphasis on sustainability and considers how future generations will be affected by the current use or management of a commons. To address sustainability issues when commoning, Gibson-Graham et al. (2013), recommend the use of a 'commons yardstick' which analyses and predicts the past, present, and future generations' use of a commons. Understanding the historical circumstances, cultural norms, and other factors at play at a given moment in time can be critical in the successful management of a commons (Bollier, 2014). The commons yardstick not only helps in the analysis that helps identify the kinds of ethical actions needed to enhance sustainable management of a commons but also those that have not worked in the past.

The commons yardstick can be used to identify when urban waterways in Nairobi began to get polluted, when pollution was recognised as a serious challenge, when remediation actions to combat pollution were initiated, whether there have been any improvements, and how the future looks under the current situation. The commons yardstick offers an opportunity to explore different pathways for how to manage urban waterways and could also be used to predict failure pathways based on past and current experiences (Gibson-Graham et al., 2013). Figure 14 below attempts to represent past and present management efforts of Nairobi's waterways in a commons yardstick based on past and present legal and institutional frameworks. A complete commons yardstick providing alternatives for the future management is discussed in chapter 6 of this thesis.

For effective commoning of a resource to occur, it is critical that there be a 'we' – a community that establishes how commons are to be managed (Gibson-Graham et al., 2013). In regard to this study, 'we' comprises residents of informal settlements living adjacent to urban waterways. A 'Commons Identi-kit' has been put forward as a commoning tool to help identify opportunities for commoning by transforming unmanaged open-access resources such as urban waterways into commons (Gibson-Graham et al., 2013). Figure 15 below shows ways of commoning enclosed property (private property) and open-access resources, of which urban waterways in Nairobi are an example. The application of the commons yardstick and Identi-kit has been discussed in details in chapter 6 of this thesis.

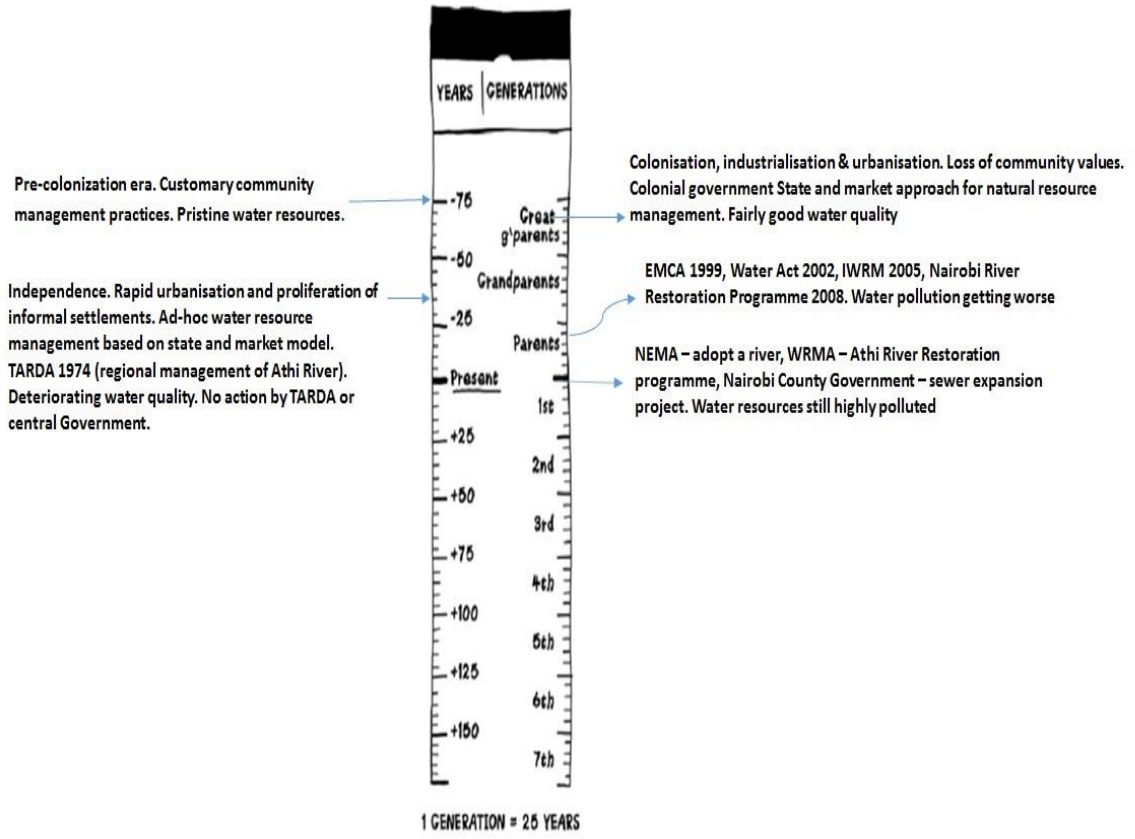


Figure 14: Commons yardstick ((Gibson-Graham, Cameron, & Healy, 2013) modified to show attempted management efforts for waterways in Nairobi .

	Access	Use	Benefit	Care	Responsibility	Ownership
Commoning enclosed property	Narrow	Restricted by owner	Private	Performed by owner or employee	Assumed by owner	Private individual Private collective State
Creating new commons	Shared and wide	Negotiated by a community	Widely distributed to community and beyond	Performed by community members	Assumed by community	Private individual Private collective State Open access
Commoning unmanaged open-access resources	Unrestricted	Open and unregulated	Finders keepers	None	None	Open access State

Figure 15: Ways of commoning enclosed property and open-access resources (adapted from Gibson-Graham et al. (2013)

The literature reviewed in chapter 1, 2 and 3 of this thesis provided the background for designing an appropriate research methodology for the actual fieldwork. The two major gaps revealed in Nairobi's waterways pollution can be attributed to exclusion of urban communities from water resource management as well as poor governace based on a hierarchical central government management approach. These two factors therefore influenced the selection of a suitable case study area for in-depth analysis, the identification of appropriate data collection procedures as well as the selection of participants for the study. This is explained in the following chapter on research methodology.

CHAPTER 4: RESEARCH METHODOLOGY

4.0 Introduction

This thesis has revealed that rapid urbanisation rates in Nairobi have largely led to an urbanisation of poverty characterised by the proliferation of informal settlements. These settlements have mainly sprouted along urban waterways and are inadequately served with sanitation infrastructure and solid waste management services. As a result, the waterways along which they lie have become prone to pollution from the settlements. Likewise, rapid population growth rates experienced throughout the city have also rendered the current sewerage infrastructure inadequate, leading to the breakdown of sewage treatment plants and the subsequent discharge of partly treated effluent in Nairobi River. However, there is hope for improvement of sanitation in the informal settlements through adoption of communal facilities as well as coproduction of sanitation infrastructure as discussed in chapter 2.

After identifying the major underlying causes of urban waterways pollution in Nairobi, the thesis examined management approaches for Kenya's urban waterways. Chapter 3 revealed that this management has followed the integrated water resource management approach as prescribed by the Global Water Partnership. This has not been very effective, especially in dealing with urban waterways pollution, as the proposed restoration plans are vague and highly generalised and do not address any specific issue in any specific area, making them unimplementable. The country has also adopted a hierarchical centralised management approach with little or no community involvement. A hierarchical management approach in itself is not a problem, but in Kenya, it has been ineffective due to poor governance, costly bureaucratic processes, and misappropriation of funds. As an alternative to this approach, chapter 3 explored the systems theory based on the panarchy framework, which advocates for control not just from the top down but also from the bottom up. The discussion on the panarchy framework culminated in a discussion of the 'commoning' practice as a way of managing urban waterways from the bottom up by actively engaging urban residents.

The previous chapters presented a general picture of the challenges facing urban waterways management in Nairobi. In this chapter, I outline the methodology that was used to obtain more specific data on the urban waterways pollution phenomenon using the selected case study of the

Mathare 4B informal settlement located along the Mathare River. This chapter was guided by revelations in the previous chapters which revealed data gaps such as little or no community engagement in urban waterways management and multiple confirmed accounts of high microbial pollution of Nairobi's waterways. These revelations were important in identifying the appropriate methodological approach to conduct the fieldwork. I adopted a mixed strategy incorporating both qualitative and quantitative methods. Qualitative methods were used to capture the views and perceptions of respondents while quantitative methods were used to establish the extent of microbial pollution in the waterways.

The aim of this research was to investigate the pollution of urban waterways within Nairobi city with a particular focus on informal settlements. I sought to answer questions of 'how and why' urban waterways are facing pollution. This was with the view of understanding perceptions and attitudes of informal settlement residents and other relevant key informants towards urban waterways pollution and exploring ways of better management. I also set out to determine the extent of microbial pollution at strategically chosen sampling points within and outside the city, focusing mainly on *E. coli* and faecal coliform parameters.

4.1 Research context

This study focusses on a phenomenon that has been prevalent in Nairobi city for decades – the pollution of urban waterways. In justifying my choice of this particular study topic, I point out the continued degradation of these urban waterways despite the formulation (and part implementation) of rehabilitation and restoration programmes, the establishment of various river-based management agencies, the promulgation of a new constitution upholding citizens' rights to a clean environment, and the existence of laws and regulations on water resource management in the country. With such a strong and seemingly solid policy, legal, and institutional framework, one could be (mis)led to imagine that urban waterways in Nairobi are some of the cleanest and best managed in the world! Unfortunately, there is nothing further from the truth.

Having been brought up and educated in the rural hinterlands of Nairobi city, my first conscious encounter with the urban waterways was much later as an undergraduate student at the University of Nairobi situated in the city. I was pursuing an undergraduate degree in urban and regional planning and it involved studying the dynamics of urbanisation as a major subject. It was just before my final year and I had an internship with a non-governmental organisation

dealing with informal settlements in Nairobi. This was a great opportunity because in the course of my studies, informal settlements had emerged as one of the greatest urbanisation challenges in Kenya. My first assignment was to assist in the mapping of a village in Mathare, one of the largest informal settlements in Kenya. It was also the first time that I was actually going to visit an informal settlement and that I would encounter the Mathare River.

The memory of my first visit to an informal settlement has stuck vividly in my mind as I got to experience firsthand an alternate world I did not know existed in the same country in which I lived. No amount of literature on the proliferation of informal settlements in Nairobi and the associated squalid living conditions could fully prepare me for the real situation as it was on the ground. The extreme, deplorable environmental conditions I encountered in Mathare 4B village were shocking to say the least. The settlement was crowded and congested, the structures were built of rusty iron sheets, the footpaths were narrow, dusty, and strewn with solid waste and wastewater, the space next to the river had patches of human excreta and heaps of solid waste, and the Mathare River was heavily laden with raw sewage and solid waste. You had to always watch your step around each corner to avoid stepping on human excreta wrapped in polyethene bags and, as I would learn later on another assignment, be always alert to avoid 'flying toilets', especially when walking next to the river.

I could not hide my discomfort as the air was heavy with not only the dust but also the stench of raw sewage. It took me a few days to adjust working in this environment. Two years after this initial assignment, my view of these urban waterways was widened when I worked as a research assistant for a PhD candidate focusing on encroachment of riparian zones in Nairobi. This experience further exposed me to other diffuse pollution sources such as industries, informal markets, quarries, and garages. I also got to visit other informal settlements located in different areas of the city along riparian zones.

In the course of these two assignments, I interacted with the people who lived closest to the waterways and observed how they interacted with these waterways. I also participated in a river clean-up exercise in one of the informal settlements. My assignments exposed me firsthand to the urban waterways pollution phenomenon in Nairobi. Eight years down the line, the waterways are as polluted as ever despite notable significant changes in governance, policy, and technology, as earlier mentioned. This situation, together with my background in urban planning, challenged

me to explore the pollution of urban waterways from a people's perspective by investigating the perceptions and attitudes of the people who interact with the rivers on a daily basis.

The decision to use an informal settlement as a case study was as a result of my own experiences working in these settlements. It was also informed by findings in previous studies designating these settlements as heavy polluters of urban waterways. I am also intrigued by the complexity of informal settlements in Nairobi and the constant attention they attract from global organisations, yet nothing seems to be getting any better. I am further motivated by the search for that delicate balance between socio-economic systems and biophysical systems and how sustainable management can be achieved, especially in a rapidly urbanising world. I specifically chose Mathare 4B village due to my earlier work there and existing contacts. It is not always easy to conduct research in an informal settlement, especially if you do not have any contacts to take you around and introduce you to the residents. Mathare 4B was conducive as I was a familiar face and the residents were familiar with my previous engagements.

4.2 Theoretical considerations

Research has been described as a form of disciplined inquiry that generates knowledge which gives people the cognitive control that helps them interact with their social and physical environments positively (Mugenda, 2008). Research is therefore vital for the sustainable management of resources such as rivers. Without knowledge, it becomes difficult to control physical processes leading to negative effects on both the socio-economic and biophysical systems. Mugenda (2008) observes that there are various sources of information that humans have relied upon over time, including experience, tradition, authority, and expert opinion. The aim of research is to build knowledge about a phenomenon or event in the world as one may experience it (Mugenda, 2008). The acquired knowledge explains phenomena that are experienced by people differently, for instance, the pollution of urban waterways.

Knowledge is acquired through various epistemological perspectives primarily concerned with the nature, origin, and scope of knowledge (Mugenda, 2008; Muketha, 2014). Epistemology is defined as a branch of philosophy that addresses the question of 'how you know what you know' and also deals with the means of production of knowledge (Mugenda, 2008; Tracy, 2012). The four main epistemological approaches employed include realism, empiricism, positivism, and

postmodernism (Mugenda, 2008). The nature of research being conducted determines the epistemological approach adopted by the researcher.

The two dominant approaches currently adopted are positivism and postmodernism. Positivists' thinking is associated with quantitative methods while postmodernist thinking is associated with qualitative methods (Mugenda, 2008). Likewise, positivism is seen as synonymous with the scientific method or the rationalistic approach while postmodernism is synonymous with the naturalistic approach. Quantitative and qualitative research is also viewed as extensive and intensive research respectively (Winchester & Rofe, 2016). Holliday (2007) further observes that social science research is complex and any attempts to distinguish it as either purely quantitative or qualitative will always suffer from oversimplification because both approaches are complimentary and go hand in hand. I adopted this view in determining the methodology for this study as it broadly constitutes social science research and the two approaches are seen as complimentary, providing a holistic approach towards explaining the urban waterways pollution phenomenon.

The postmodernist and positivist approaches have been recognised as equally sound after decades of positivist dominance in research. Winchester and Rofe (2016) cite the differences between the two research methodology approaches as follows: quantitative research seeks to answer fundamental questions about either the relationship between phenomena and places or the differences between them, while qualitative research is concerned with social structures or individual experiences. However, this comparison should not be seen as creating a dichotomy as the two approaches use methods that are almost similar (Holliday, 2007; Mugenda, 2008). Therefore, according to Mugenda (2008), the better way to distinguish positivist and naturalist paradigms is by their basic axioms (assumptions), namely views about reality, cause-and-effect relationships, views about knowledge and truth, and views about the relationship between the inquirer and the object.

In regard to views about reality, positivists believe that in order to explain a phenomenon, one should be able to describe it, predict its occurrence, and highlight factors that cause its occurrence with a reasonable degree of measurement. This is based on the assumption that there is a single tangible reality fragmented into quantifiable variables and processes that can be studied independently of each other (Mugenda, 2008). For instance, in this study, microbial

contamination of urban waterways was singled out from a variety of other water quality parameters such as chemicals and heavy metals and analysed independently. Measurement is central to the positivist's paradigm, and for this study this was done through counting faecal coliform colonies present in water samples collected at different sampling points.

On the other hand, postmodernists assert that there are multiple intangible realities which can only be studied holistically (Mugenda, 2008). This approach is more concerned with the meanings people ascribe to tangibles rather than with the tangibles themselves. This view is reflected in this study as I sought to understand the meaning residents and key informants ascribe to urban waterways rather than just obtain numerical data on microbial contamination of the waterways. Postmodernist proponents believe that it is futile to expect a convergence of the multiple realities into one common reality since people will always have different perspectives on similar issues (Holliday, 2007; Mugenda, 2008).

In regard to cause-and-effect relationships, positivists argue that causality is the centerpiece of the universe and should be the main subject of human knowledge. Positivists believe that the best way of testing causality is through experiments and also in the use of statistics to estimate and minimise errors (Holliday, 2007). Postmodernists are of the position that there can be no certain way of determining cause-and-effect relationships. They instead believe in multiple factors that interact with feedback loops to shape each other. This has been referred to as reciprocal causation, where causes are inseparable from effects. Postmodernists believe that an action is understood not as having been caused but as having emerged from constant interplay of its shapers (Mugenda, 2008). In essence, this alludes to a panarchy system consisting of continuous interaction between socio-economic and biophysical systems with feedback loops between the systems which determine their sustainability, degradation, or permanent change in state (as discussed in chapter 3). In this study, the socio-economic system is represented by the informal settlement while the biophysical system is the urban waterways. This will be discussed further in the conceptual framework.

The relationship between investigator and study is another axiom that distinguishes positivists and postmodernist approaches. For the positivists, a discreet distance should be kept between researcher and the object of inquiry to maintain objectivity and avoid bias. This was the case for me during the collection of water samples where in order to yield unbiased results, I had to

observe recommended procedures to ensure that the samples collected were not contaminated before they were analysed under specific controlled laboratory conditions. However, in postmodernist inquiry, researcher and respondent interact and influence each other as the researcher is actually the main instrument registering all observations through his/her mind (Tracy, 2012). As such, Mugenda (2008) and Tracy (2012) both agree that self-reflexivity about one's goals and biases is important.

Preferences in terms of data collection methods also differs, with positivists often preferring quantitative data collection methods to get mathematical data with greater precision, while postmodernists often prefer methods that can deal with data not easily translated into numbers. Postmodernists explore methods such as interviews and observations. The postmodern approach is seen as flexible, adaptable to emerging situations, and insightful. There is therefore no need for the researcher to begin with a precise problem statement, theory, or method.

Postmodernist inquiry prefers grounded theory – which emerges from data collected – as opposed to a priori theory (Tracy, 2012). Grounded theory is described as a systematic inductive analysis of data made from the ground up – a bottom-up approach (Tracy, 2012). The approach assumes that the research problem guides and bounds the study as opposed to the theory. In addition, the postmodernist further utilises his tacit knowledge to strengthen study design as the inquiry unfolds (Mugenda, 2008). By definition, tacit knowledge is knowledge which is not easily shared. It constitutes habits and culture that people are not consciously aware of. Mugenda (2008) views tacit knowledge as important because of its far-reaching implications, especially in policy formulation and project implementation. An example is given where a lack of application of tacit knowledge leads to misguided and therefore inadequate policies or misguided implementation of good policies that still end up in failure. This is important in this study as I have previously noted the failure of the urban waterways restoration and rehabilitation projects in Nairobi city despite the existence of policies and laws. This failure may have been as a result of such a lack of tacit knowledge.

The last distinguishing axiom between positivist and postmodernist approaches is quality of study findings. The positivist school of thought judges quality of findings through internal/external validity, reliability, and objectivity. On the other hand, Mugenda (2008) broadly characterises criteria used to judge qualitative data as having four dimensions: credibility,

transferability, dependability, and confirmability. Credibility is demonstrated by establishing connection between data and the phenomenon under investigation. This is done by documenting all multiple realities as portrayed by the people and by sharing a preliminary findings report with respondents so that they can confirm that it is representative of their views, thus giving them an opportunity to make any change. Transferability is noted as not being the driving force of postmodernist inquiry: the only concern is to develop a comprehensive idiographic statement of the phenomenon under investigation. Idiographic in this context refers to depth rather than breadth, as will be discussed later under research design. Dependability in a postmodernist perspective is likened to reliability under the positivism regime. Postmodernists believe that it is not necessary to have designs that are replicable; they rather believe in providing other researchers with different designs to obtain information on the same problem (Mugenda, 2008). Confirmability is likened to objectivity under positivism. For postmodernists, the interest is on the objectivity of the data and not the researcher (Mugenda, 2008).

Triangulation is therefore used to bring in a variety of data sources, perspectives, different methods, and different researchers to cross-check data and interpretations. The researcher also has the option of using a reflexive journal to uncover the underlying epistemological assumptions and justifications. Self-reflexivity is defined as "a researcher's awareness of the effects that he/she might have of the information that is provided by respondents" (Mugenda & Mugenda, 2012, p. 274). In order to achieve sincere research, the researcher is required to 'demonstrate awareness, self-critique, and vulnerability in their research, to their audiences and themselves' (Tracy, 2012, p. 249). Table 2 below shows a set of criteria developed by Tracy (2012) that summarises and explains the key elements for establishing quality in qualitative research.

Quantitative studies have previously been carried out within the Nairobi River Basin measuring/assessing various water pollution parameters such as heavy metals, chemicals, and bacterial pathogens (Maingi, Musyoki, Suleiman, & Mbithi, 2013; Musyoki et al., 2013). The proposed restoration and rehabilitation of the Nairobi River Basin followed a quantitative study carried out by government in conjunction with UNEP. However, there exists a data gap in terms of the qualitative aspect of urban waterways pollution and it is my assumption that this gap has led to the failure of urban waterways restoration programmes.

Table 2: Criteria for judging quality in qualitative research (Tracy, 2012, p. 230)

Criterion for quality (end goal)	**Various means, practices, and methods to meet the criteria**
Worthy topic	The topic of the research is relevant, timely, significant, and interesting.
Rich rigor	The study uses sufficient, abundant, appropriate, and complex theoretical constructs, time in field, samples, contexts, and data collection and analysis processes.
Sincerity	The study is characterised by self-reflexivity about subjective values, biases, and inclinations of researcher, as well as transparency about methods and challenges.
Credibility	The research is marked by thick description, concrete detail, explication of tacit knowledge, and showing rather than telling; triangulation and crystallisation; multi-vocality; member reflections; and inter-coder reliability (when collaborating on data analysis).
Resonance	The research influences, affects, or moves particular readers or a variety of audiences through aesthetic, evocative representation; naturalistic generalisations; and transferable findings.
Significant contribution	The research provides a significant contribution conceptually/theoretically, practically, heuristically, and methodologically.
Ethical	The research considers procedural ethics (such as human subjects), situational and culturally specific ethics, and relational ethics.
Meaningful coherence	The study achieves what it purports to be about, uses methods and procedures that fit with its stated goals, and meaningfully interconnects literature, research questions/foci, findings, and interpretations with each other.

4.3 Research design

I adopted a mixed strategy encompassing aspects of both the positivist and postmodernist paradigms, thus generating both quantitative and qualitative data. The qualitative aspect focused on the exploration of how and why urban waterways are polluted, and the perceptions and attitudes of informal settlement residents and key informants. This involved identifying and interviewing residents and key informants from government and academic circles in order to carry out a qualitative assessment. The phenomenon under investigation entailed understanding the interaction between people and urban waterways and the underlying drivers of these

interactions in an effort to build new knowledge that could be useful in urban waterways management.

The quantitative aspect of the study focused on the extent of microbial contamination of urban waterways at different locations characterised by different uses of adjacent land. I sought to generate statistical data on the extent of microbial pollution at strategic points along the waterways. The map showing these sampling points is in chapter 5 shown as figure 21. The quantitative data thus generated served as an indicator of the relative contribution of microbial loads by the case study area and the sewage treatment plant. It also gave an indication of the effects on downstream users.

Overall, I opted for the case study approach incorporating both qualitative and, to some extent, quantitative methods. A case study is defined as "a research approach that seeks to achieve an in-depth understanding of a phenomenon, event or occurrence within its real life context" (Mugenda & Mugenda, 2012, p. 39). A case study is further defined as a bounded system with its various parts working together, be they a person, organisation, or social group (Mugenda & Mugenda, 2012). In regard to this study, it is both a place and a social group comprising residents of the selected informal settlement village, Mathare 4B. The use of a case study approach is recommended when the research seeks to answer the question of 'how' or 'why', the researcher has no or little possibility of controlling the event, and the phenomenon being studied is a contemporary one (Yin, 1994).

A case study is further seen as an approach to research design rather than as merely a method of collecting data (Baxter, 2016). This is because the case study approach may deal with qualitative or quantitative work or be a mixture of the two. The importance of depth and context in case studies is explained by Baxter (2016), who observes that case study research is intensive and not extensive. Two terms that have been used by social scientists to describe this difference are idiographic and nomothetic research. Idiographic research refers to depth-oriented research focusing on understanding a phenomenon in more detail, while nomothetic research is breadth-oriented, focusing less on details and more on investigating a limited number of phenomena across several cases simultaneously (Baxter, 2016). This research, in seeking an in-depth understanding of the phenomenon under investigation through use of a case-study approach, can therefore be distinguished as idiographic.

Baxter (2016) broadly classifies case studies into four types: theory-testing and theory-generating case studies, case studies across time and space, cross-sectional and longitudinal case studies, and comparative analysis case studies. My case study falls primarily into the theory-testing/theory-generating and cross-sectional types. This is because these two types helped inform the kind of case study to be used in this research. For a study with well-developed propositions, the researcher can choose to use theory testing emphasising deductive logic, where the researcher collects data which supports or falsifies the concept under investigation (Baxter, 2016). On the other hand, where there is a requirement that ethnography and grounded theory be easily incorporated into the design, case studies may be selected in view of generating theory. Practically both positions are a matter of degree since even the most ethnographic and grounded theory practitioners do not commence fieldwork without adequate knowledge of some theory (Baxter, 2016). Classifying a case study research solely as either theory-generating or theory-testing may be problematic, as it is in the case of my research.

Qualitative research is neither purely deductive nor inductive but rather more cyclical in the sense that theory stated initially as hypotheses or propositions is explored (deductively) by studying the real world of the case and then information obtained is used to generate new concepts (theory) to explain what is observed (inductively) (Baxter, 2016). In this regard, I cannot classify this study as solely theory-generating or theory-testing because there was some degree of both aspects. However, the case study was cross-sectional in the sense that it was conducted at a specific point in time (Baxter, 2016).

The proposed research sought to investigate a social phenomenon that has led to the pollution of urban waterways with potentially harmful effects for downstream users and aquatic ecosystems. The aim of the research fit well with the case study design as it sought to find out how and why informal settlements contribute to pollution of urban waterways. Gillham (2010) points out that a qualitative method in the case study design focuses primarily on the type of evidence that will give an understanding of what is going on. This is important particularly for my study given that previous government efforts to clean up the rivers have not been successful.

Case study design allows the researcher to ‘get under the skin’ of a group or organisation and perceive their reality from the inside (Gillham, 2010). My case study offered insights on people’s behaviour, thoughts, and feelings towards pollution of urban waterways. Case study–based

research provided the flexibility for me as the researcher to explore existing theory and also develop grounded theory based on the evidence obtained, and this may be useful in generalising how residents in other informal settlements perceive and interact with urban waterways. The results from this case study may be seen as transferable as there are a number of informal settlements adjacent to urban waterways in Nairobi with relatively similar conditions.

4.4 Data collection and field procedures

The unit of analysis for this research was an informal settlement adjacent to an urban waterway. Specifically, Mathare 4B, a section of the Mathare informal settlement adjacent to the Mathare River, was selected for in-depth analysis. The analysis focused on the actions, behaviours, and perceptions of the residents in regard to the Mathare River and how they interact with the river generally. The units of observation were Mathare and Nairobi Rivers in the city as well as the Athi River further downstream, where the effects of pollution were assessed using the quantitative approach. This entailed collecting water samples that were analysed for *E. coli* and faecal coliforms associated with disease-causing bacterial pathogens. Quantitative data previously collected along these rivers was also used to help demonstrate the extent of microbial pollution on these waterways.

A case study generally employs various data collection methods that may include documentation, observation, interviews, questionnaire administration, participant observation, and use of archival records (Gillham, 2010; Mugenda, 2008; Yin, 1994). I chose the following methods for this study: interviews, direct observation, collection of water samples, use of archival records, focus group discussions, and documentation. These are discussed below.

4.4.1 Review of existing literature and previous research results

The existing and available information on the subject under investigation from a global and local perspective was reviewed firstly to highlight the relevance of urbanisation to the pollution of urban waterways as it relates to informal settlements. Secondly, previous research undertaken by authors such as Muketha (2014), Karisa (2010), Maingi et al. (2013), and Musyoki et al. (2013) was used to highlight aspects of the phenomenon under investigation from different perspectives ranging from riparian zone conservation to assessment of microbial pollution in the urban waterways in Nairobi. The relevance of these studies to my research assisted in not only conceptualising the problem statement but also providing detailed quantitative data which was

not within my means to acquire firsthand due to limited resources. The findings of quantitative studies by Maingi et al. (2013) and Musyoki et al. (2013) provided a comprehensive assessment of the extent of the pollution of urban waterways in the entire city concentrating not only on the microbial aspect but also on chemical and heavy metals parameters. Likewise, qualitative studies by Muketha (2014) and Karisa (2010) detailed the urban waterways pollution menace from a riparian zone conservation perspective, highlighting the perceptions and attitudes of the people within their respective study areas and the importance of riparian zone conservation as a means of reducing the pollution.

4.4.2 Qualitative field research

The qualitative aspect of this study sought to obtain data from the residents in terms of their perceptions and attitudes towards the Mathare River adjacent to their settlement. This was to specifically address the study's research objectives:

1. To conduct survey and focus group discussions to explore how residents perceive and interact with urban waterways.
2. To establish, from residents and key informants, the major causes of urban waterways pollution and how best to mitigate it.
3. To document observed current uses of urban waterways traversing informal settlements and how these affect water quality.
4. To collect and analyse water samples for bacterial pathogens along the informal settlement and further downstream.
5. To review urban waterways management practices with the view of informing an effective sustainable management strategy.

To achieve objectives 1 and 2 above, semi-structured interviews and focus groups were used to obtain qualitative data from both residents and key informants in terms of their perceptions and interactions with urban waterways.

Semi-structured interviews involved the use of an interview guide (attached as Appendix B) focusing on the issues I felt were relevant to the study. An interview guide is seen as flexible and allows for discussion of relevant questions not previously contained in the guide (Dunn, 2016). The selection of key informants was based on the relevance of the role they played in the

management of urban waterways as well as city planning. The initial list of key informants identified for interviews included representatives from the Nairobi City County's Department of Environment, the Nairobi City Water and Sewage Company (NCWSC), the National Environment Management Authority (NEMA), the Water Resources Management Authority (WRMA), and the University of Nairobi. The key informants were selected to shed light on the phenomenon as professionals, practitioners, and scholars who are widely exposed to the phenomenon in their daily work. The informants were also to share their perceptions, opinions, and attitudes towards the pollution of urban waterways traversing informal settlements and give recommendations for better management (the interview guide for key informants is attached as Appendix C). Note-taking was used to record data emerging from semi-structured interviews.

Three focus groups were held in Mathare 4B to discuss the phenomenon of urban waterways pollution from the residents' perspective. A focus group is defined as a discussion of a specific topic, presented by a researcher, involving a small group of between six and ten people (Cameron, 2016). The focus group is considered an ideal method of acquiring social knowledge as it invokes debates that produce multiple meanings that people ascribe to places, relationships, and processes (Cameron, 2016). This was manifested during the focus groups in the study area where participants gave different views and engaged in brainstorming sessions as to the best way to reduce pollution in the urban waterways. My role as the researcher was to moderate and guide the discussion ensuring that focus on the subject was maintained. I used an audio recorder to capture the discussions after obtaining oral consent from the participants. This was preferred over note-taking as it allowed me to focus on the debates more keenly without the distraction of trying to write notes and keep up with the discussion at the same time. It facilitated smooth and uninterrupted discussions.

The three categories of focus groups in this study included a general residents' focus group including men and women, a women-only focus group, and focus groups with youth groups. The focus groups were conducted in the village's community hall. The selection of participants for each focus group was facilitated by the community chairman[5] who was able to contact available

[5] The community chairman is not politically elected but rather chosen by residents and serves a more traditional community leadership role, such as dispute resolution between neighbours and advocating for the residents' needs to elected leaders.

residents to participate. The community chairman acted as the gatekeeper and entry point for me into the settlement and hence played a major role in helping organise focus groups. However, this could also be seen as a shortcoming due to the bias of leaving the selection process to the community leader, and to compensate for this, I conducted random interviews with other individuals living next to the river to get their perspectives as well. This helped in triangulating the data and increasing validity and reliability. I also requested of the community leader that he try as much as possible to get a representative group comprising members from each corner of the village, which he assured me he did. Each focus group comprised five to ten members and discussions lasted between 45 minutes to one hour. The focus group discussions question guide is attached as Appendix D.

In consideration of ethical issues, the women's focus group was conducted by a female research assistant to create a free environment where women could discuss issues without reservations. The research assistant was trained beforehand and also attended the general residents' focus group before conducting the women's focus group. This was to ensure that she was able to gain some confidence and skills on facilitating a focus group and thus obtain relevant, high-quality data.

Objective 3 above was achieved by the use of the participant observation method. Observation is defined as accurately watching and recording phenomena as they happen (Kearns, 2016). The purpose of observation is to count, complement, and/or contextualise. Although these purposes of observation are seen as not mutually exclusive, as pointed by Kearns (2016), I specifically adopted the observation method for complementary purposes to gain additional descriptive data which could add value to the interviews and focus group discussions. It was also particularly useful in capturing events I had not anticipated prior to embarking on fieldwork. For instance, during one of my walks along the river in the case study area, I observed a well-constructed culvert outlet discharging what appeared to be raw wastewater directly into Mathare River. It was clear that this was not waste generated within the settlement and upon inquiring from residents I was informed that it was from a middle-income area approximately 10 km away from the river.

I used the observation method to describe and record the activities that could impact these waterways. In terms of river observation, the method was used to make an assessment of the

state or condition of the river and also establish types of pollutants going into the river. I also observed how people were interacting with the river and the activities being conducted next to and in the river. For instance, there were residents who were collecting building stones and metal scraps from the river for sale. I used photography to capture the condition of the river and also took field notes to document observed activities.

To achieve objective 5 of the study, I used document review (written and electronically stored) to obtain data on the management of urban waterways from a global perspective and how these apply to the local context of urban waterways in Nairobi. I organised the theme of urban waterways management around the concept of 'commoning', which is about the collective management of 'common pool resources' with a strong emphasis on engagement of local communities or residents. The approach could be viewed as a paradigm shift from the more common bureaucratic approach involving central management authorities that use a typical top-down approach in water management with little or no involvement of affected communities. Writers such as Bollier (2014) and Gibson-Graham et al. (2013) provided perspectives and examples of how commoning can be used as a tool in the sustainable management of common pool resources such as urban waterways. Legislations such as the Water Act and the National Environmental Management Act were reviewed to establish provisions for the management of waterways in Nairobi. Policy documents such as the water resources strategic plan for the country and the proposed Athi River Rehabilitation Programme (ARRP) were also reviewed to establish approaches being used to manage the affected urban waterways.

The primary and secondary data obtained as part of attaining these objectives constituted the qualitative aspect of the study. The quantitative aspect was addressed by objective 4, as explained below.

4.4.3 Quantitative field research

To achieve objective 4 of the study, I used a quantitative approach to enable the assessment of microbial pollution in the urban waterways in the study area and further downstream. Gillham (2010), observes that quantitative data has a special place in a case study as it extends range of evidence on the topic and qualifies lessons learnt from other studies. It provides cross-referencing, which is part of the internal validity of a case study. The research targeted one

source of quantitative data for the case study: the measurement of faecal coliform contamination of the rivers under investigation.

Water quality analysis specifically targeted the measurement of faecal coliforms present in the urban waterways as a result of informal settlement pollution. Identification of sampling points took consideration of the river continuum with the view of showing the extent of contamination at different points and establishing if there was any dilution effect. Sampling points were identified in a systematic order (upstream going downstream) as follows: before flowing into the informal settlement (case study area), after flowing through a section of the case study area, after confluence with the main waterway with cumulative upstream loads from other settlements in Mathare, before discharge from the sewage treatment plant, at the last treatment pond of the plant, after discharge from the treatment plant, and 50 km downstream at a recreational site (shown in figure 21 in chapter 5). Comprehensive monitoring data from previous quantitative studies conducted within and outside the city was also used to give an indication of the situation not only in the city but also further downstream. This data on previous sampling was also compared to the primary data obtained to see if there was any change since the studies were conducted.

Overall, this research design and the methodological approach adopted were effective in explaining the urban waterways pollution phenomenon using multiple sources of evidence. It assisted in addressing the objectives of the study and answering the research questions under each objective. Gillham (2010) observes that multiple sources of evidence help the researcher acquire different kinds of evidence, including what people say, what the researcher observes them doing, what they make or produce, and what documents show. All this evidence is then put together into a narrative presenting a chain of evidence (Yin, 1994).

4.5 Ethical considerations

Before conducting fieldwork, I had to fulfil the research ethics requirements for the University of Canterbury. Research ethics is viewed as being about the conduct of a researcher and his/her responsibilities towards all those involved in the research, including sponsors, the general public, and targeted respondents who are the subjects of the study (Dowling, 2016). The purpose of considering ethics before fieldwork is to ensure that the researcher's responsibilities towards

targeted participants with regard to matters of privacy, informed consent, and harm are observed (Dowling, 2016).

Privacy and confidentiality is about protecting the private details of participants from the public and also storing data in a safe, locked place where access is restricted (Dowling, 2016). It also entails protecting the identity of participants by using pseudonyms to ensure anonymity. However, some participants may choose to have their real names quoted in the study, as was the case for my research. In this case, I obtained oral consent, which was captured on an audio recording device. The research assistants also signed confidentiality agreements stating that they would treat all information and data related to the fieldwork as confidential. Confidential agreements for research assistants are attached as Appendix E.

The second ethical consideration pertains to informed consent, which is basically about making the participants fully aware of the details of the research before they decide to participate or not (Dowling, 2016). The key informants were provided with detailed information sheets and a consent form to sign before beginning the interviews. This is attached in this thesis as Appendix F. A prepared statement was read out to residents who participated in the focus groups detailing what the study was about and requesting consent to proceed. This is attached as Appendix G. The residents' assent to participate in the study was captured on an audio recording device.

Research should also take into account the possibility of bringing harm to participants or the researcher (Dowling, 2016). In the ethics application, I demonstrated that my research posed a low risk to the participants as well as the researcher. The planned focus groups and interviews with residents did not present any risk to the physical or emotional well-being of the participants and the researcher. This is because the issues being discussed were not private, taboo subjects but rather public issues on the pollution of urban waterways. Having satisfactorily addressed all ethical issues for my proposed fieldwork, the ethics application was approved by the University of Canterbury's Human Ethics Committee, after which I was able to proceed with fieldwork.

4.6 Data analysis

Latent content analysis was used to analyse the data obtained through the semi-structured interviews with residents and key informants. This method constructs common themes that emerge from the interviews based on the main questions asked or the topics discussed (Dunn,

2016). The semi-structured interviews were not audio-recorded and hence transcription was not necessary. This method of analysis was effective in capturing a variety of responses to the same question and revealed areas where respondents were in agreement as well as where they had divergent viewpoints.

Analysis of focus group data begun during the focus group discussions, as recommended by Cameron (2016). This entailed listening carefully to the discussions and seeking clarification on unclear, contradictory, or ambiguous statements (Cameron, 2016). Transcription of the audio recordings for each focus group was completed within two days after the meeting; this was done with the help of my research assistants to make sure that we captured all the data. The transcribed data was then organised under common themes under the main research questions of the study, thus capturing all the views and perspectives from the four focus groups. I also took note of representative or revealing statements made by participants, many of which I went on to quote in this study to illustrate key perceptions and attitudes of the residents in regard to the management of urban waterways.

Water samples collected for this study were sent to a laboratory for analysis of levels of *E. coli* and faecal coliforms. Although I was not allowed entry into the laboratory, I was informed that a standard procedure using Petrifilm plates was used to grow bacteria colonies in an incubator. The Petrifilm method, as explained by UN-HABITAT (2010a), entails the following. A Petrifilm plate designed for *E. coli* analysis is placed on a flat surfaced and labelled with the location, date, and time of the sample being tested. The top film is lifted and 1 ml of sampled water is placed onto the centre of the red circular plate, taking care not to touch its surface. The top film is then slowly unrolled down onto the sample to prevent any entrapment of air bubbles. A plastic spreader is then placed on top of the plate and a gentle downward pressure applied to its centre in order to distribute the sample evenly across the plate, taking care not to slide the spreader across the film. The spreader is then removed and the plate left undisturbed for one minute for the gel to solidify. Lastly, the Petrifilm plates are incubated with the clear side up at approximately 35°C for up to 24 hours. After incubation, the Petrifilms will indicate if there is any presence of coliforms. *E. coli* colonies will appear blue with gas bubbles while non-*E. coli* coliform colonies will appear red. It is then possible to count the number of colonies formed to determine the

extent of *E. coli* and coliform contamination in the water samples. Some photographs of Petrifilm results for the sampling points are annexed as Appendix H.

4.7 Study limitations

The major limitation of this study is that not all key informants in government agencies were willing to participate. Unfortunately, some of the vital key informants, such as representatives from the Nairobi County Department of Environment and the Nairobi City Water and Sewerage Company (NCWSC), declined to participate in the study. These are the organisations which bear the greatest responsibility in regard to the phenomenon under study and their unwillingness to participate in the study was revealed by the results of quantitative data obtained. The data obtained indicated that in fact the treatment plant under the management of the NCWSC was indeed the highest contributor of microbial loads into the river due to the discharge of high volumes of partly treated sewage. On their part, the Department of Environment, County of Nairobi is directly in charge of all urban waterways in the city and their unwillingness to participate in the study could be an indication of their failure to fulfil their mandate as stewards of these waterways.

The selection of participants for the focus groups was facilitated by the village chairman with the possibility that selected participants may not have been a true representation of the entire village. This could have affected the dependability of the data obtained. To compensate, I used a convenience sample to interview residents living next to the waterway as a way of triangulating and increasing the dependability of the data obtained.

Having had to conduct the fieldwork within a limited period of two months I was not able to obtain all the data I had set out to collect. For instance, I would have wanted to conduct focus groups further downstream outside the city and interview people who relied on water flowing out from the city for their daily use. I would have also wished to collect more water samples in the downstream areas where it is consumed to determine the extent of contamination as a result of pollution in the city. This is therefore an area that I would recommend for further research, especially as discussions with some key informants indicated negative health effects experienced downstream as a result of people consuming contaminated water flowing from the city.

CHAPTER 5: FAILURE OF URBAN WATERWAYS MANAGEMENT IN NAIROBI AND FUTURE POSSIBILITIES

5.1 Introduction

This chapter reveals the results of data collected in the case study area, Mathare 4B, as outlined in chapter 3 (research methodology) of this report. During fieldwork, I set out to find out the perceptions and attitudes of informal settlement residents and key informants on urban waterways management. I also planned to collect water samples at eight strategic points along waterways within and outside Nairobi to test for microbial contamination. The research adopted a case study approach encompassing both qualitative and quantitative methods in collecting fieldwork data. I relied on focus group discussions with community members and youth groups involved in environmental activities to obtain the residents' perceptions and attitudes. I also conducted convenient semi-structured interviews with residents living adjacent to the Mathare River and documented my own observations to compensate for any biases from the focus groups.

Another aspect of the fieldwork was interviews with key informants representing some of the government agencies involved directly and indirectly in water resource management in Nairobi city. Agencies involved directly are those that are mandated to protect and conserve waterways, while those involved indirectly mainly deal with infrastructure provision such as sewage infrastructure provision and also maintenance of sewage treatment plants. It was important to get perspectives of indirectly involved agencies because the treated sewage eventually ends up in the Nairobi River and areas lacking sewer line connections dump human waste in the rivers as well. I also held interviews with lecturers from the University of Nairobi whose areas of interest were urbanisation and water resources.

In this chapter, I present findings based on the semi-structured interviews and community focus group discussion with the residents under common emerging themes. I then present the findings of the two community youth groups' focus group discussions on what they are currently doing in regard to urban waterways and the challenges and opportunities they identified. This will be followed by the views of key informants from academic circles and government agencies on their approach towards better management of urban waterways. I conclude this chapter by presenting the results of the microbial contamination tests performed on the water samples

collected within and outside the city. My field observations are also captured and mainly represented in this chapter through captioned photographs and descriptive write-ups of what I observed throughout the data collection exercise.

To capture perceptions and attitudes of Mathare 4B residents, I held two focus group discussions – one with community members and the other with a group of women in the village. Using convenience sampling, I conducted semi-structured interviews to compensate for biases that may have emerged in the participant selection process for the focus groups. However, I first present a historical perspective of Mathare 4B as explained by the residents during the community focus group discussion. It explains, from their point of view, how the settlement was established and how it has been growing over the years and also highlights the major challenges that residents have been facing and continue to face.

5.2 History of the Mathare Valley and Mathare 4B Village

According to the residents who attended the focus group discussion (FGD), Mathare 4B village was established in the 1960s after the country gained independence from Britain. Initially, there was quarrying in the Mathare River Valley to extract building stones. People began occupying the quarries after they were abandoned. Generally, the main tribes living within the Mathare Valley are Kikuyu and Luo, but there is also a presence of other tribes such as Luhya and Kamba. The residents have no land tenure rights as their settlement is on government land. They are given ballot papers, but these only act as proof of structure ownership. The majority of residents are tenants, with some landlords living in the settlement but most living outside Mathare 4B.

One of the greatest challenges facing Mathare 4B, as explained by the community-recognised village leader, Charles Odhim, is negative political influence turning tribe against tribe, especially during the election periods. He captured the volatile political situation in the settlement as follows:

> …when the country's general elections approach, it becomes very problematic. We as residents and citizens don't have any problems with each other, but politics coming from our political leaders above incite tribal hatred and this gets into the hearts of individuals. That was especially the case during the post-election violence of 2008 which affected many residents, forcing some to move out of the settlement. But naturally, politics aside, we live like brothers and sisters and even

> the community leaders do not discriminate against any person based on tribe or other factors. (Charles Odhim, Mathare 4B community leader)

This shows that the residents of Mathare 4B and indeed other settlements generally live and co-exist peacefully, but destructive politics aimed at creating chaos for political mileage has been a major problem, destroying the delicate social fabric of informal settlements in Nairobi.

Another challenge is that the study area has very narrow access roads as a result of congested development. This is a major hindrance for medical or fire outbreak emergency response teams. The residents observed that since the devolution process that saw the establishment of county governments in the country, there have been some attempts to widen the access roads and improve accessibility, but some areas are still inaccessible. The residents noted that more needs to be done in order to open up the entire settlement in terms of access. The residents do not feel safe due to a high incidence of crime.

The settlement faces numerous environmental challenges. Women present at the focus group discussion raised the issue of poor sanitation, in particular highlighting the lack of facilities to dispose of used sanitary towels. This waste is therefore disposed casually in the settlement and may end up in multiple places, including the surrounding environment as well as the Mathare River. The residents also complained of poor river water quality due to extensive pollution attributed to the lack of toilets and dustbins to dispose of both liquid and solid waste, as explained by one resident during the focus group discussion:

> The situation here is really bad because we have a very high population but very few toilets and dustbins where we can dispose solid waste. So you find people rather than burn the solid waste, they find it easier to throw it in drainage channels and in the adjacent river. In addition, we have temporary toilets which all discharge in the river. Therefore you find that when the river comes from upstream, Karura Forest, the water is clear, but once the river gets into the settlement, the water changes colour because all wastes from drainage channels and toilets are directed to the river. There is a main sewer line which is still under construction but no connections have been made yet. (Resident, community focus group)

5.3 Community uses for the Mathare River

From the semi-structured interviews and focus group discussions, while some of the respondents felt that the Mathare River was of some use to them, the majority indicated that they saw the river as of no use because it was highly polluted and was a health hazard to children and residents in general. The residents of Mathare 4B stated that they use Mathare River for several purposes. Firstly, they use it for disposing of human and solid waste, including used sanitary towels, as mentioned in the women's focus group; the river flushes the waste downstream. Secondly, they use it for cooling local alcoholic brews, and again any waste after the brewing process is discharged into the river. Thirdly, it is used for extinguishing fires in case there is an outbreak. Fourthly, it is used for washing clothes and bathing in the upstream area of the settlement where the water is still relatively clean. Fifthly, it is used for irrigation for subsistence urban agriculture. And lastly, the river is a source of water and stones for construction purposes in the settlement.

The residents pointed out that the Mathare River was important to them as it provided the cheapest (free) and most convenient way of discharging human waste generated in the settlement. Three ways are used to accomplish this: firstly, by strategically positioning the toilets next to the rivers for easy discharge (as shown in figure 16 below); secondly, by having a network of pipes or channels connecting toilets further within the settlement to drain sewage into the river (as shown in figures 17 and 18 below); and thirdly, using the 'wrap and toss' ('flying toilet') method. The respondents also felt that the rivers were vital for disposing of other solid and liquid wastes as the settlement lacked a dumping site and did not have any waste collection services from the city authorities.

The residents also pointed out that not all waste going into this segment of the Mathare River is generated by their settlement; some is generated by middle-income and commercial areas located further away from the river. These neighborhoods have constructed culverts to discharge their raw sewage into Mathare River. An example is pictured in figure 19 below.

Figure 17: Toilet strategically positioned to discharge directly into the river. Mathare 4B settlement, Mathare River (Photo: Kevin Kienja, 2016)

Figure 16: Pipes draining toilets which arelocated further within the settlement. Mathare 4B settlement, Mathare River (Photo: Kevin Kienja, 2016)

Figure 18: Pipes draining toilets which are located further within the settlement. Mathare 4B settlement, Mathare River (Photo: Kevin Kienja, 2016)

Figure 19: Constructed channel leading from another neighbourhood draining wastewater into the Mathare River. Mathare 4B settlement, Mathare River (Photo: Kevin Kienja, 2016)

The residents of Mathare 4B stressed that the reason the river is used for the above mentioned purposes is that the settlement has inadequate solid waste management and the river is seen as the best channel available to them to receive and transport their solid waste away from the settlement. Another reason to explain current uses of the Mathare River was that the settlement lacked adequate sanitation facilities and was not connected to the municipal sewerage system. Therefore, almost all human waste generated in the settlement ends up in the Mathare River, which acts as a natural flushing system for the settlement. Some residents also felt that when people build houses very close to the river or within the riparian reserve, Mathare River is exposed to pollution as it makes it convenient for people to easily throw waste into the river. Lastly, a lack of close proximity to available toilets in the settlement was another contributing factor leading to discharge of human waste in the river. The residents pointed out that the toilets that exist are closed at 9:00 pm, after which residents are forced to use improvised means such as 'flying toilets' directed into the rivers or any other means close at hand.

However, the residents felt that if the Mathare River was not as polluted as it is now, they could ideally use it for domestic purposes including consumption. The river could also be used for recreational activities such as swimming, fishing, and irrigation.

5.4 Residents' idea for improving the condition of the Mathare River

The residents of Mathare 4B were able to give their thoughts concerning the best measures that can be applied to improve the condition of the river. In response to a suggestion of regular river clean-up exercises, one participant was unequivocal about addressing the root causes of the pollution problem rather than the symptoms, stating:

> You cannot come up with the solution of cleaning up the river before solving the problem of sanitation and solid waste management. The first thing that should be given priority is to address the challenges that residents face. If it is lack of toilets, provide adequate toilets; if it is solid waste, plan for a dumpsite and regular collection by local authorities. Give the people a reason not to dump in the rivers – otherwise all efforts are futile without alternatives for sanitation and waste disposal. The river is cleaned up today and tomorrow people start dumping all over again. (Mathare 4B resident)

To address the sanitation problem, the residents stated that temporary toilets built on the banks of the river should be demolished. They suggested construction of more community toilets and connecting them to the main municipal sewer system. Households sharing each community toilet block could then share connection costs and monthly payments for water and sewerage services. The residents suggested that community toilets should be located in close proximity to their users to avoid the inconvenience of walking long distances to access a toilet, especially at night. One of the residents had the following to say about connecting toilets to the new sewer line:

> The problem we have is lack of following up. So far we have seen the sewer line get constructed in our settlement but nobody has taken the initiative to follow up on what should be done next. So our community leaders should follow up and find out the charges for connection and monthly fees. Our representatives should negotiate for the fees to be subsidised as most of us here cannot afford to pay much… it is not a good sight to see your own human waste flowing in the river and maybe even your own child is somewhere along that river playing with the water... life is changing and we must also change. (Mathare 4B resident)

In regard to solid waste management, residents pointed out that space for a dumping site should be provided where all waste from Mathare 4B can be deposited to await collection from city authorities. To ensure that city authorities collect waste from the settlement, residents suggested that extra garbage trucks be provided, especially to informal settlements, to increase coverage and efficiency. The women also suggested that facilities for disposing of used sanitary towels should be provided and maintained on a daily basis. Residents were confident that by providing toilets and dealing with solid and sanitary waste management, the root causes of river pollution will be addressed, and then the river clean-up process could begin.

For effective conservation and protection of the Mathare River, the residents suggested that a minimum riparian zone be established along the river. This space could be as little as one metre to avoid displacing many residents whose structures are as close as one metre away from the edge of the river. Trees could then be planted along this zone to strengthen the riverbank and also provide a recreational strip for the residents. To do this successfully, residents pointed out that NEMA should play an active role in collaboration with the residents. The residents mentioned that this has successfully been done in Majengo, another informal settlement in Nairobi, and that it has reduced and even prevented the disposal of solid waste into the river in the area. They suggested that residents whose structures maybe affected by the minimum riparian zone could be compensated and relocated to provide space for tree planting.

Other measures to improve the condition of the river mentioned by the residents included creating awareness of river conservation, community collaboration with all relevant organisations in terms of restoration and service provision, each resident being a custodian of the river, support for youth groups ready and willing to conduct river conservation activities, burning and recycling solid waste instead of dumping it in the river, and putting up signs along the river bank to discourage people from dumping. The residents suggested that after implementation of all these measures, penalties could then be set for any person who is found polluting the river.

Even as the residents discussed ways of improving the condition of the river, they also pointed out some of the current efforts already being undertaken. These included the National Youth Service cleaning up of the river by removing the solid waste, construction of a sewer line (as shown in figure 20 below) by the government (yet to be connected to settlement toilets), demolition of some toilets that were built on the riverbank that directed waste into the river,

construction of several new community toilets, and residents volunteering to take part in the clean-up process.

Figure 20: A sewer access hole on the main sewer trunk constructed in Mathare 4B. Mathare 4B settlement, Mathare River (Photo: Kevin Kienja, 2016)

When questioned about what else needed to be done and by whom, the residents suggested various agencies that could play a vital role in the fight against river pollution. Participants discussed various roles that government agencies, international agencies, NGOs, and the community should play in managing urban waterways. At the community focus group discussion a heated debate ensued about whether it is the community members or the government who should take responsibility for the river. Some participants felt that residents had a stewardship role to play while others felt that there were people getting paid to do that job in government. Below is an excerpt of this debate:

> *Researcher*: In your opinion, whose responsibility is it to clean and maintain Mathare River?
>
> *Participant 1*: All of us as a community…

> *Participant 2*: No! No! No... Not us. There are those commissioners in the government sitting in their offices and getting paid for that. And when we had a very strong minister in charge of the environment he pushed them to work and we saw them – officers from NEMA and other organisations in charge of waterways management. At the time they tried and it worked for highly polluted areas in the city like Gikomba market; and when the minister left office, they disappeared too. So, there is someone somewhere seated in his office being reluctant to do his job. So we as a community will only chip in when we see these government officers do their job… but we cannot chip in while people sit in their offices and get paid for doing nothing. They must do their work. Then we will contribute.

The youth groups interviewed also felt that it was the collective responsibility of the community to maintain and improve river conditions. They pointed out that the only thing needed for this to happen was facilitation in terms of tools and equipment. This is encapsulated in a comment from one of the members of the Ghetto Rangers youth group:

> We have taken it upon ourselves to keep the environment and the river clean as a youth group and as a community… we discourage residents from using flying toilets as one way of keeping the river clean but instead to use the community ablution blocks. We are trying our best to sensitise the people and so far we have achieved some results. We successfully collected solid waste deposited under one of the footbridges crossing Mathare River and discouraged residents not to dump waste, and so far the site is still clean… the only thing we are lacking to successfully clean and protect the river is tools and equipment such as protective gloves and gumboots. (Ghetto Rangers youth group member)

This debate shows that residents feel some sense of responsibility as a community for the river but also that the relevant government agencies responsible for providing them with services such as sanitation and solid waste management have failed them. As a result, this somehow diminishes their sense of responsibility as they feel they cannot contribute much to maintaining a clean river when they have been denied services and technical as well as financial facilitation by key government agencies which have the capacity to do so.

The debate also revealed roles to be played by UNEP as the global trend-setter in environmental matters. Participants felt that UNEP had failed to do anything considerable to address the issue and pointed out that they believed UNEP had a strong role to play. Some residents pointed out that UNEP had provided facilitation for a river clean-up exercise some years back and that was

the last they heard of UNEP. The residents stated what else they felt needed to be done and the persons and institutions they felt should be responsible. This is summarised in table 3 below.

Table 3: Summary of residents' responses about urban waterways' responsible stakeholders

Stakeholder	Role
Nairobi City County Government	• Build more toilets • Ensure no houses are built on the river's riparian reserve • Connect all toilets to the sewer line • Collect solid waste regularly from the settlement
National Environmental and Management Authority (NEMA)	• Create community awareness as to the importance of environmental cleanliness • Provide trees to the community to be planted on the riparian reserve to act as a conservation measure • Clean up the river
Politicians, especially the Member of the County Assembly (MCA)[6]	• Support the youth and community members who are willing to clean the river by providing support such as protective gloves and boots
The local community	• Stop dumping waste into the river • Connect to a new sewer system after negotiation of affordable rates • Help in the cleanup process
United Nations Environmental Programme (UNEP)	• Facilitate river cleaning and restoration
National government through the Ministry of Public Service, Youth and Gender Affairs	• Help with cleaning up of the river and the construction of toilets

[6] The MCA is a politically elected leader representing the smallest political unit (ward) in the county government assembly.

5.5 The role of youth groups in managing urban waterways

I held two focus group discussions with youth groups in Mathare 4B engaged in sanitation and environmental conservation activities. This was with the view of establishing how community-organised groups in the settlement have been addressing the issue of Mathare River pollution and also finding out the challenges they face. I also sought to assess the viability of active community engagement in the sustainable management of urban waterways such as Mathare River. The youth groups in question were Ghetto Rangers and You and I. In this section, I present results on how these groups were established, what they do, the challenges they face, and opportunities they identified for a more proactive role in managing urban waterways.

You and I was started in 2004 with the primary aim of bringing young people together in Mathare 4B to engage in constructive community activities and discourage negative behaviour. A group member explained the main reason for establishing the group:

> The group was established to unite the youth in the settlement and encourage positive behaviour. Initially, there was no garbage management in the settlement. People used to dump rubbish everywhere, even on other people's doorsteps. Also due to inadequate toilets, there was human waste all over the settlement. So the main agenda of the group was to at least keep Mathare 4B clean. (Wycliffe Odhiambo, group member, You and I)

You and I has attempted to keep the settlement clean in two ways. Firstly, they have been providing community members with garbage disposal bags for a small fee. They then collect garbage from the households on a weekly basis and place it at a strategic point for collection by city authorities. They however pointed out that city authorities rarely come around to collect the solid waste. Secondly, the group maintains a community ablution block and keeps it clean, charging a small fee to residents using it.

Ghetto Rangers was formed in 2005. This group comprises both young women and men who felt that they could assist the Mathare 4B community in regard to sanitation and maintaining a clean environment. The group manages a community ablution block and undertakes community clean-up on a weekly basis. The main reasons for forming the group, as mentioned by the members, were to reform youths who were idle and engaging in negative activities such as theft and drug abuse; to engage in community activities such as cleaning the environment and maintaining the community ablution block; to empower themselves through the income they generate, for

example, through supplying polyethene bags to the community at a small fee for garbage collection; and to bring the youths together and share ideas as to how to better the community.

The two youth groups also engage in community sensitisation on the importance of not dumping waste into the river, as narrated by a member of Ghetto Rangers:

> As we distribute the garbage disposal bags to households, we also talk to the residents and discourage them not to throw rubbish in the river but rather to use the bags which we collect on a weekly basis. However, individuals are different and we still have stubborn community members who still dump in the river, but mainly at night. We also encourage residents to use our ablution block rather than the 'flying toilets', but then again there are people who do not listen. We have also tried to discourage people from defecating next to the river, but this still happens, especially at night. It's really hard… it's not easy, but we try our best to talk to the people. (Joseph Kuria Ghetto Rangers youth group)

The youth group members noted that cleanliness in the settlement has considerably improved since they started their activities.

The Ghetto Rangers youth group intends to undertake other projects, such as starting a carwash, to generate more income. The group has savings which they use for the welfare of the group members. For example, if a member gets sick they can assist by paying hospital bills, and they also can pay school fees for the children of group members. The two youth groups aim to always maintain the community interest above individual interests, and they demonstrated this by facilitating the connection of their ablution blocks to the municipal water supply so that people could wash their hands after toilet use. They have also undertaken to provide soap for handwashing.

The two youth groups identified various challenges they faced in conducting their activities in Mathare 4B. They pointed out that they have inadequate materials and tools. These include tools used by the groups in cleaning the toilets, environment and river such as rakes, wheelbarrows, gumboots, and hand gloves. A lack of equipment, especially protective clothing, exposes the members to hazards such as broken bottles, used syringe needles, and polluted water. A lack of financial and technical assistance from the central and county government, especially in regard to repairing and maintaining the ablution blocks, was another major challenge mentioned. The youth groups claimed that almost half of the toilets in their ablution blocks were not usable,

leading to people resorting to open defecation and 'flying toilets'. With the help of the central and county governments and other sponsors, they felt that the toilets could be repaired and kept available to residents for their use. Lastly, the youth groups mentioned uncooperative residents who continue dumping waste into the river as much as the group tries to keep the river and environment clean and educate them on the importance of this.

Even in the face of these challenges, the youth groups have persisted and feel that some opportunities exist for their environmental maintenance efforts to bear fruit. They observed that unity among the group members and the youth groups' vision of putting community interest above individual interest is the engine that drives their efforts even in the face of what may seem like a hopeless situation. They have cultivated a culture of honesty, transparency, and trustworthiness among group members, which also helps in management of the groups' financial returns from their activities. In addition, the groups have created employment opportunities for their members who assist in maintaining the ablution blocks and in collecting solid waste at a fee. The groups have also created opportunities for Mathare 4B residents to have access to clean toilets. Therefore, these youth groups act as a good entry point for any organisation or institution interested in conducting environment-related activities such as improved solid waste management, improved sanitation, and restoration of the Mathare River.

The youth groups pointed out that to effectively engage in the sustainable management of the river, they needed to be empowered through strong collaborative efforts with key government agencies. This is especially true in regard to areas they felt were beyond their scope and ability to tackle, such as renovating the ablution blocks and effectively managing solid waste in the settlement. They pointed out that while they collect waste and place it at a strategic point for city authorities to collect, this collection rarely happens, and they do not have the capacity to transport it to the city's dumping site themselves. Youth group members also emphasised the need for collaboration with other agencies to clean and conserve the urban waterways as they do not have the technical capacity, tools, and expertise to do it on their own. In addition, they suggested collaborative education programmes to create awareness around the need for a clean environment, with emphasis on the river. They said this could be done through organising workshops and seminars in the settlement and that they were willing to assist in mobilising and sensitising community members.

5.6 Perceptions and views of key informants on urban waterways management

This category consisted of scholars whose areas of interest include urbanisation and urban waterways, and officials working with organisations involved in the management of urban waterways. The scholars were willing to participate in the research and gave invaluable information on the subject. To this effect, I interviewed two lecturers from the University of Nairobi dealing with urban planning issues and pollution of the city's urban waterways. On the other hand, officials from from governmental organisations with jurisdiction over urban waterways– either directly or indirectly – were seemingly reluctant to participate in the study: out of a possible seven, I managed to interview only two participants, representing NEMA and the Athi Water Services Board (AWSB). Information on how other government agencies are influencing urban waterways management was obtained using secondary data and is presented in chapter 3 of this thesis.

The key informants interviewed pointed out that the rivers in Nairobi are the receiving environment for most types of discharge, including sewage, industrial effluent, and chemicals from flower growers within and around the city. The urban waterways are also used for the following other purposes: domestic and institutional use, irrigation for urban agriculture, and as a cooling system for the brewing of traditional liquor. The respondents further pointed out that these current uses result in the heavy pollution of urban waterways.

The major causes of pollution as mentioned by the key informants are related to the ways the urban lands along the rivers are currently used. For instance, the key informants pointed out that there is discharge of raw industrial and sewage effluent into the waterways due to absence of proper wastewater disposal facilities and poor enforcement by relevant government agencies. They also identified inadequate provision of sewerage infrastructure, especially in middle- and low-income neighbourhoods, as a major cause of urban waterways pollution. Informal commercial activities also generate waste that is disposed in adjacent rivers. Lastly, the key informants observed that there was uncontrolled farming along riparian zones in some parts of the city leading to erosion and chemical run-off into the rivers.

The respondents noted that the pollution of urban waterways has continued unabated due to poor enforcement of laws and policies on pollution, thus leading to the uncontrolled release of waste

into waterways. The key informants also mentioned that the existing sewer system does not have the capacity to treat the waste currently being generated in the city and thus discharges partially treated effluent into Nairobi River. The final cause of pollution mentioned was the perception that riparian zones are 'free' or 'idle lands' leading to their encroachment and subsequent pollution of the waterways.

The key informants felt that a number of measures would help in reducing pollution in the urban waterways. Firstly, the university lecturers emphasised the need for land-use control along riparian belts, the upgrading of informal settlements, and the sensitisation of riparian communities. Secondly, all informants were in agreement about the need for improved provision of sanitation facilities such as sewage and solid waste management. Thirdly, one of the university lecturers interviewed insisted on adopting a human approach in managing urban waterways through, for instance, making upstream communities aware of pollution effects on downstream communities which rely on these waterways for consumption. And lastly, the informants agreed on the importance of adopting a strong legal approach (enforcement of policies and regulation; punishment of offenders) especially for industrial pollution and sewage treatment plants.

The lecturers pointed out that the current institutional management structure in regard to Nairobi's urban waterways is more than adequate. Institutions mentioned included WRMA, NEMA, and NCCG. However, the lecturers pointed out that there is a need to strengthen capacity within key government agencies as well as increase collaboration between the institutions and agencies involved.

The two major challenges mentioned by key informants were limited funding for urban waterways restoration and lack of coordination between the two levels of government (national and county). It was observed that the community and the private sector prefer to take the easiest and cheapest ways out, leading to urban waterways pollution. For instance, industries will discharge untreated waste to save on treatment costs while communities will discharge raw sewerage and solid waste into urban waterways to avoid paying council fees for these services. Inadequate capacity of management agencies was also mentioned as a key challenge as it leads to inadequate provision of infrastructural services (to deal with sewer and solid waste) and poor control of development leading to encroachment on riparian zones. Other challenges mentioned

were lack of data, ignorance of local stakeholders, and lack of sensitisation around the benefits of urban waterways conservation.

The key informants identified that there is an opportunity for rallying communities to take ownership of and improve their neighbourhood as more and more people become aware of the bad state of their environment. There are also opportunities for empowering the youth to act as custodians of urban waterways and creating employment opportunities for them. It was also suggested that authorities change their approach from the monitoring of polluters such as the informal settlement residents to working with them in order to find a lasting solution to the problem rather than the current situation of accusations and counter-accusations from both sides. There is potential for innovation as to how to improve the situation – the chance to have a paradigm shift in terms of the management of urban waterways. Finally, it was observed that it is possible to have clean water in urban waterways and restore destroyed aquatic ecosystems if all stakeholders were to work together and all responsible government agencies fulfil their mandate.

5.7 Extent of microbial contamination of urban waterways: Sampling results

To determine the extent of microbial pollution associated with the discharge of human waste in the urban waterways, I collected water samples for analysis for *E. coli* and total coliforms. Identification of sampling points took into consideration the river continuum in the view of revealing the extent of contamination at different points and establishing whether there was any significant dilution effect. Sampling points were scheduled in a systematic order (upstream going downstream) as explained in chapter 4 and as shown in figure 21 below.

The water sampling results after laboratory analyses are presented in table 4 below. The table also includes the recommended standards in Kenya for *E. coli* and total coliforms in rivers. The results indicate high counts of *E. coli* and total coliforms at all the sampling points, an indication of the presence of human faeces in all the sampled urban waterways. This confirms that urban waterways in Nairobi are contaminated with raw sewage not only from informal settlements but also from the city sewage treatment plant as well as other middle-income and commercial areas not adjacent to the river (as previously shown in figure 19). The implications of these results are further discussed in the next section of this chapter.

Table 4: *E. coli* and coliform sampling results for the Mathare, Nairobi, and Athi Rivers

Sampling Point	*E. Coli* (cfu/100ml)	Coliforms (cfu/100ml)	Kenyan National standard
P1 – Thika Road; Mathare River tributary	400	3,700	*E. coli:* nil/100ml Total coliform: nil/100 ml
P2 – Mathare 4B; Mathare River tributary	1000	4,200	
P3 – After Mathare 4B; Mathare River	700	6,700	
P4 – Nairobi River before sewage treatment plant	400	No clear results	
P5 – Sewage treatment plant, last pond	700	No clear results	*E coli*: nil/100ml Total coliform: 30/100 ml
P6 – Nairobi River after discharge of sewage treatment plant	8,000	12,600	*E. Coli:* nil/100ml Total coliform: nil/100 ml
P7 – Athi River; Fourteen Falls recreational site	1,100	10,200	

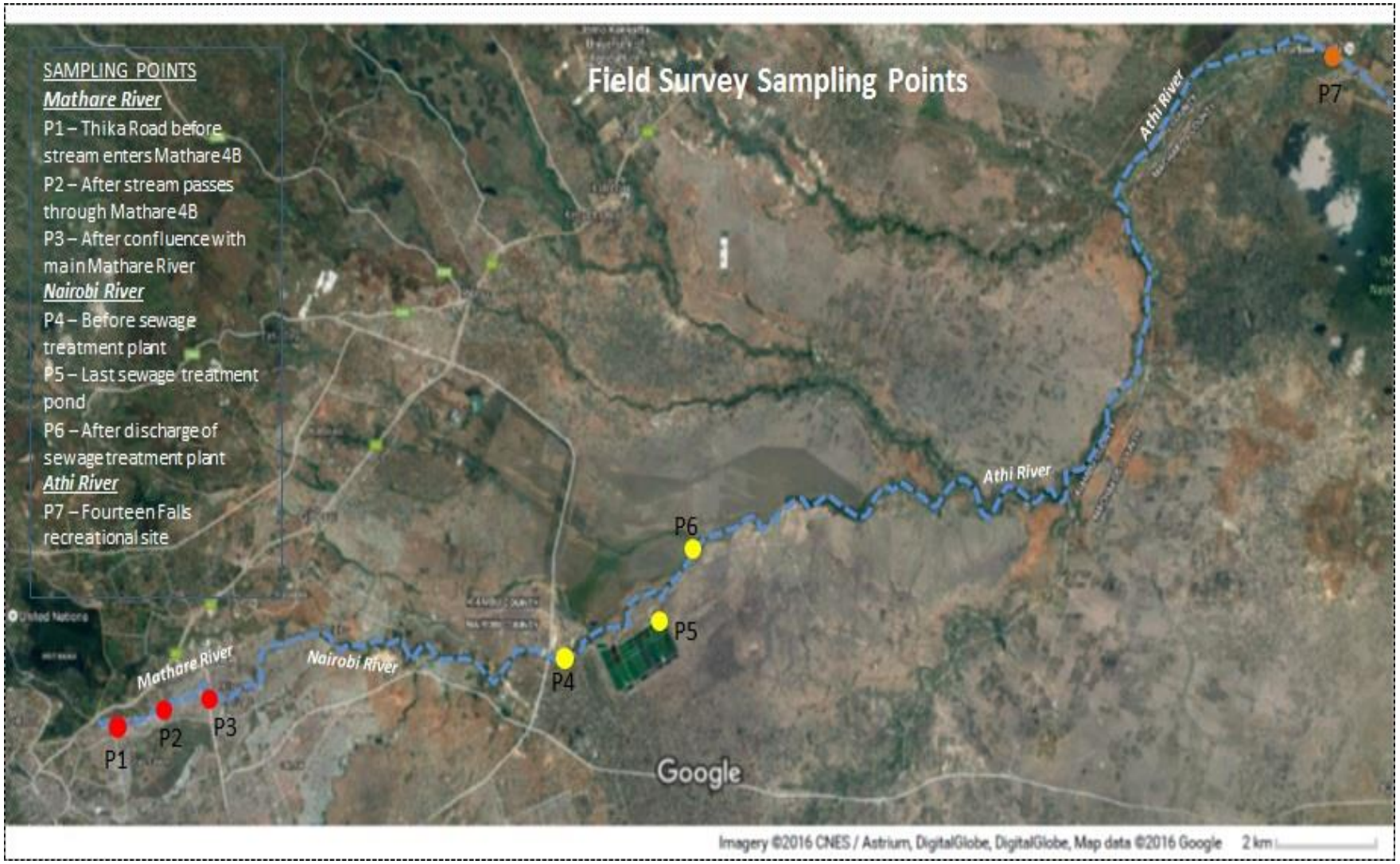


Figure 21: Field survey sampling points

The results presented in this chapter capture the current situation of the Mathare River as it traverses Mathare 4B. The results have shown how the residents of Mathare 4B interact with the Mathare River and the reasons behind this kind of relationship. The residents identified the challenges they face and also suggested solutions towards improving the river management. Also, the key informants interviewed gave their views as to how urban waterways should be managed to reduce pollution and improve water quality. The results have also revealed the extent of microbial contamination not only in the Mathare River but also the Nairobi and Athi rivers further downstream from the case study area.

5.8 Implications of results

This thesis has discussed the failure of central government-driven, hierarchical management of urban waterways in Nairobi, in chapter 3. This chapter has provided evidence of this by giving specific examples relating to Mathare 4B. The results presented in this chapter can be classified into four groupings addressing the research questions. These include the perceptions and attitudes of Mathare 4B residents, the role of youth groups in the management of the Mathare River, the opinions of key informants, and the empirical data showing the extent of microbial pollution in Nairobi city's urban waterways. All these discussion points provide evidence of the current pollution situation in Mathare 4B and other parts of the city and form the key foundation for discussing sustainable management of urban waterways.

The first research question posed in this thesis was, '*What are the perceptions of informal settlement residents in relation to urban waterways and how do they interact with the waterways?*' This chapter has revealed that perceptions of residents influenced the purposes to which the residents put the Mathare River which in turn constituted the major ways through which the river was polluted. The perceptions and attitudes of residents towards the river revealed that the people of Mathare 4B have no sentimental attachment to the river and view it only as a convenient and free way channel for disposing of wastes generated in the settlement. This answers the third research question for this thesis, which was, '*What functions do the urban waterways serve for informal settlement dwellers?*' We note that the lack of sentimentality towards the river may be influenced by the fact that most residents in Mathare 4B are actually tenants and have no ownership rights over either the structures or the land.

The second research question posed in this thesis was, '*What are the major causes of pollution of the urban waterways adjacent to informal settlements?*' The reasons given for this were that firstly, that Mathare 4B has inadequate solid waste management services and secondly, that it lacks adequate sanitation services as the settlement is not connected to the city's municipal sewer system. This means that most solid waste and sewage generated in Mathare 4B almost certainly ends up in the Mathare River, thus constituting a key source of river pollution. This has in turn adversely affected water quality in the urban waterways. The perceived illegitimate status of informal settlements is a major factor that has led to the inadequate provision of sanitation facilities and solid waste management services on the part of relevant city authorities. This marginalisation has only led to dismal living conditions for the residents and increased pollution of urban waterways.

The key informants interviewed in this study echoed the views of Mathare 4B residents in acknowledging that urban waterways traversing informal settlements are highly polluted as a result of the disposal into the waterways of solid waste and raw sewage. These key informants also observed that poor urban planning had in large part contributed to the proliferation of informal settlements along riparian zones. They also pointed out that the failure of city authorities to recognise the legitimacy of these settlements and their consequent denial of sanitation services had only made the pollution dilemma worse. This, combined with the existence of other types of pollution sources, has made the Nairobi River Basin the most polluted in the country, as pointed out by Karisa (2010) and other researchers.

The fourth research question that the thesis sought to address was, '*How does pollution of urban waterways affect water quality for downstream communities?*' To answer this question, I collected water samples at seven strategic points along the Mathare, Nairobi, and Athi rivers. The field data obtained from water sampling revealed high counts of microbial pathogens (*E. coli* and total coliforms), well above the recommended national standards for both fresh river water and treated sewage effluent, as shown in table 4 earlier in this chapter. This is consistent with previous sampling surveys conducted on urban waterways in Nairobi by Musyoki et al. (2013) and others. Kenya's national standards stipulate that *E. coli* should be undetectable in river water and in treated sewage effluent. Total coliforms should also be undetectable in river water and at a minimum of 30 cfu/100 ml in treated sewage effluent.

The presence of *E. coli* in water is used as an indicator of the possible presence of other, more harmful disease-causing microbes such as cryptosporidium, giardia, shigella, and norovirus.

The results of water samples obtained are significant to this study as microbial pathogens have been known to contaminate meat (from animals drinking contaminated water) and leafy vegetables (irrigated with contaminated water), and once these are ingested by humans, they can cause diseases such as haemorrhagic diarrhoea. The results are also significant in regard to recreational activities. This is because contact with contaminated water can cause gastrointestinal illness as well as skin, ear, respiratory, eye, neurologic, and wound infections. Therefore, the excessively high levels of *E. coli* and total coliforms recorded in urban waterways in Nairobi pose a great health risk for downstream users who use the water for recreation, irrigation, and domestic consumption.

From the sampling results we also note that the pollution trend increased gradually from the upper areas of the city, when the waterways are entering Nairobi, towards their exit points out of the city. Before the Mathare River entered the study area (Mathare 4B), *E. coli* and total coliforms counted were the lowest for the entire survey, at 400 and 3,700 cfu/100 ml respectively. After passing through Mathare 4B, there was a considerable increase of *E. coli* and total coliforms, to 1,000 and 4,200 cfu/100 ml respectively. This can be attributed to the discharge of raw sewage along the Mathare 4B section of the river. Going further downstream, there was a sharp increase after discharge of "supposedly" treated sewage from the largest city sewage treatment plant; *E. coli* and total coliforms recorded at this point were 8,000 and 12,600 cfu/100 ml respectively. These readings clearly reflect that the sewage treatment plant is discharging only partially treated sewage into the Nairobi River, a conclusion also previously reached by Maingi et al. (2013) and others. It is therefore clear that the sewage treatment plant does not have the capacity to treat current volumes of human waste being generated in the city and that the treatment plant might in fact represent the highest microbial contaminant of urban waterways in Nairobi, considerably higher than the informal settlements as revealed by statistical data.

By the time the Nairobi River exits the city, it is heavily contaminated with sewage effluent, and this was reflected at the last sampling point, Fourteen Falls recreational site. *E. coli* and total coliforms recorded at Fourteen Falls, approximately 50 km outside the city were 1,100 and 10,200 cfu/100 ml respectively. Although there was a dilution effect for *E. coli*, total coliforms increased and also the *E. coli* were found to be way over the national limit. This is attributed to excessive sewage discharge in the city as well as presumably along other points outside the city. As a result of the high *E. coli*, and total coliforms recoreded, any contact with water at this recreational site could be harmful to visitors, yet as of the time I conducted

fieldwork, the site was open, with visitors being charged an access fee to the falls. Some people occasional dipped their feet in the water but there was no swimming observed. This in some sense represents negligence by the County Government of Kiambu, which manages the site. How do you charge people to access a highly polluted and foul-smelling site that exposes them to the risk of disease? The visitors getting into contact with the water seemed oblivious of the appearance, smell, and worse still, the health risks they were exposing themselves to.

Overall, the results of the water samples I obtained confirmed that urban waterways in Nairobi are highly polluted with raw sewage. Even the lowest *E. coli* and total coliform levels recorded for this study – of 400 and 3,700 cfu/100 ml – are way over the limit of Kenya's national standards of nil cfu/100 ml. This just goes to show how critical the urban waterways pollution phenomenon is in Nairobi city. Having established the effects of pollution on water quality in the urban waterways, I then engaged residents and key informants in discussions about what needs to be done to improve the situation.

The fifth research question posed in this thesis was, '*What measures can be put in place to reduce the pollution of urban waterways and promote their sustainable management?*' The residents were unequivocal in terms of what they felt needed to be done in order restore the Mathare River and keep it clean. They pointed out that it was high time that the root causes of the problem were addressed rather than just the symptoms. They viewed river clean-up exercises and other restoration measures as only treating the symptoms, and therefore futile. The residents were of the opinion that the sanitation and solid waste challenges should be addressed first as they are the root causes of Mathare River pollution. Only upon improving sanitation and solid waste management services did the residents feel that restoration and maintenance of the Mathare River ought to begin. The key informants were of the same mind, though they framed it in a different way, observing that informal settlements upgrading will be vital in the fight against the pollution of urban waterways as it will provide basic sanitation services for the residents. Without sanitation infrastructure and solid waste management, the pollution will only continue.

This led to discussion about a new sewer line recently constructed in Mathare 4B by the Nairobi City Water and Sewage Company (NCWSC). The residents observed that although the new sewer line has been built within Mathare 4B, toilets had not yet been connected. When questioned about this new sewer line, some residents observed that they would be

willing to have the toilets connected only at a subsidised, affordable fee. Other residents were of the opinion that they could not afford to pay for the connections and the monthly charges owing to their disadvantaged financial position generally as the poorest people in the city, surviving on less than a dollar per day. Indeed, it can be argued that financial precariousness is the reason they are living in informal settlements to begin with, since they cannot afford conventional housing served with conventional water supply, sewage and solid waste management services. Since the residents did not know much about the new sewer line, I reviewed secondary data in order to shed some light on the issue.

The literature I reviewed revealed that the NCWSC has already proposed a customised payment structure for connecting informal settlements to the city sewerage system. Connection to this system also means connection to city water services, which are also lacking in informal settlements. To that effect, the NCWSC has proposed to charge the targeted beneficiaries a uniform connection fee of KShs 1,648 for a water connection and KShs 1,648 for a sewer connection. An additional capital cost recovery fee of KShs 150 per month over three years for a water connection and KShs 450 per month over five years for a sewer connection has also been suggested to repay the commercial loan taken by NCWSC to cover a significant portion of the construction cost of the sewer line. Consumers will also be expected to pay the monthly fee for water and sewerage services as determined by NCWSC. Considering that these are low-income settlements, there is no guarantee that residents will chose to connect to the sewer lines given the associated connection costs and the subsequent monthly payments, as revealed by residents of Mathare 4B. This creates another problem as it presents the possibility of landlords charging higher rents to tenants in order to cover water and sewage services. Two questions therefore arise: firstly, will the residents who were willing to connect to the municipal sewer find these charges affordable and acceptable? And secondly, what are the financial implications for informal settlement residents and will they be able to afford increased rent to cover sewage and water costs?

Residents of Mathare 4B also felt that the solid waste management situation could be improved by city authorities providing solid waste management infrastructure such as dumping bins and by ensuring regular weekly garbage collection. The residents also suggested reclamation of a minimum width riparian zone to act as green recreational space as well as a protection buffer for Mathare River. In addition, they mentioned sensitisation of the community and collaboration with government and non-governmental organisations as other ways through which the pollution dilemma could be resolved. The residents felt that they

could be actively engaged in the management of Mathare River through established youth groups in the settlement as well as alongside other community members. In so doing, the residents would be creating a new culture of collective responsibility as well as coming up with a value system for the Mathare River – and this in itself represents a pathway for commoning, as discussed by Gibson-Graham et al. (2013) and other proponents of this concept.

CHAPTER 6: TOWARDS THE SUSTAINABLE MANAGEMENT OF URBAN WATERWAYS IN NAIROBI

6.1 Introduction

This study set out to examine the pollution phenomenon affecting urban waterways traversing informal settlements in Nairobi city – its causes and effects, as well as possible pollution management options. The study sought to generate an in-depth understanding of the circumstances surrounding pollution in these urban waterways by using a case-study approach, as explained in the methodology chapter. The main focus was informal settlements, which present a particularly complex situation due to their unique nature as compared with other forms of settlements in Nairobi. As revealed in chapter 2 of this thesis, informal settlements in Nairobi are associated with the urbanisation of poverty, which occurs where a country experiences urbanisation growth rates that outpace economic development, thus leading to an increase in poverty in towns and cities (Zhang, 2016). Urbanisation of poverty has led to the proliferation of informal settlements in Nairobi, with current projections indicating that the population in informal settlements will continue to increase. In addition, city authorities do not recognise the legitimacy and legality of these settlements and thus do not provide them with vital infrastructure and services as they do other parts of the city.

The literature reviewed in this study has shown that the proliferation of informal settlements in Nairobi city has mainly occurred on vacant public land that settlers view as 'free' such as riparian zones and railway and road reserves (Githira, 2016; Karisa, 2010; Muketha, 2014). This was the case in regard to Mathare 4B, the case study area, which developed along the riparian zone of the Mathare River. It is estimated that over 83% of residents in the Mathare informal settlement are tenants and the remaining 17% own their structures (UoN & UCB, 2011). Low ownership is significant to this study, especially in regard to informal settlement upgrading as well as attempts to engage residents in playing a more proactive role in urban waterways management. It has created a sense of detachment in tenant residents not only from the settlement itself but also from the surrounding environment, including the rivers, as the majority of residents do not have legal ownership rights over the structure or the land.

The location of informal settlements next to urban waterways combined with low ownership rights as well as inadequate sanitation infrastructure and solid waste collection services has left Nairobi's urban waterways vulnerable to pollution. This pollution has adversely affected water quality for users both within the city and in areas downstream. This issue is of great

concern for the downstream area as it comprises mainly arid and semi-arid lands whose communities rely solely on water flowing from the city for irrigation and domestic consumption. Previous sampling results of river monitroing conducted by Musyoki et al. (2013) and others have revealed that waterways in Nairobi contain unusually high loads of microbial pathogens due to inadequate sanitation infrastructure, especially in informal settlements. These results were validated by the results of the water sampling I conducted in the case study area and further downstream outside the city.

Chapter 3 of this thesis also revealed that the current urban waterways management structure in Kenya has not been successful in dealing with the pollution problem. Bureaucratic government processes and attempts at integrated water resource management (IWRM) as prescribed by the Global Water Partnership (GWP) have only led to loss of funds and the formulation of vague, wide-scope, non-specific and thus unimplementable plans, as pointed out by Biswas (2004). The examples of the proposed Athi River Restoration Programme (ARRP) and the failed Nairobi River Rehabilitation Programme (NRRP) were presented in chapter 3 of this thesis to highlight the failure of central government management. There is also a lack of collaboration between government agencies, leading to a disjointed effort in addressing the urban waterways pollution problem. The central government agencies have also failed to effectively involve urban residents in the management of urban waterways. This was supported by findings, presented in chapter 5, that residents of Mathare 4B did not even know that there was a proposed restoration programme for rivers within the wider Athi River Basin. The residents were not even aware of the existence of the Water Resource Management Authority, the key government agency in charge of water resource management throughout the country.

As a result of the failed current hierarchical urban waterways management structure in Kenya, I adopted a systems approach to conceptualising the pollution phenomenon in chapter 3. This represents a non-hierarchical and holistic way of exploring the pollution phenomenon at all scales, from the household/settlement level all the way to the regional level. This conceptual framework was presented as a panarchy (nested adaptive cycle) later in the chapter. It is from this conceptual framework that I identified one of the major gaps leading to the continued pollution of urban waterways as the lack of community involvement as a result of a rigid hierarchical government management structure marred by excessive bureaucratic processes. This was supported by the views and perceptions of residents in Mathare 4B as well as two lecturers interviewed from the University of Nairobi.

However, the field data revealed that despite all the challenges faced by informal settlements, residents expressed their willingness to actively participate in the management of the waterway that passes by their settlement. This was especially the case for the youth groups I interviewed in Mathare 4B. These groups are currently engaging in maintaining a clean and healthy environment in the settlement by promoting the use of ablution blocks and assisting in the collection of solid waste as well as river cleaning exercises. Their ability to unite towards a common interest without any funding from external organisations is testament to the views of Elinor Ostrom, who disputed Garrett Hardin's presumption of the inevitable destruction of commons when left in the hands of communities. The youth groups have acted in the best interest of the environment as well as helped improve residents' living conditions by trying to improve sanitation and solid waste management. They have also influenced residents to keep the settlement clean, as evidenced by the fact that when they distribute garbage disposal bags to residents, they take time to talk to them and discourage them from dumping waste into Mathare River.

There exists an opportunity, therefore, to actively engage the youth and other interested residents in collective management of Mathare River. In addition, the key informants pointed out that while the current water resources management structure in Kenya is adequate, agencies need to collaborate and actively involve affected residents if any meaningful river restoration programmes are to be sustainable.

This chapter therefore addresses how the sustainable management of urban waterways in Nairobi can be achieved based on the literature reviewed as well as the primary data collected. In this chapter, I discuss the possibility of 'commoning' the urban waterways of Nairobi to reduce pollution levels by actively involving urban communities that live near the riverbanks. My view – which aligns with those of proponents of commoning such as Bollier (2014); Ostrom (2015), and Gibson-Graham et al. (2013) – is that management of urban waterways is best done by the communities that interact with them on a daily basis with government agencies playing a supporting role. The results have revealed that the youth groups and some other residents felt that they should be actively engaged in urban waterways management, thus representing an opportunity for commoning. In this chapter I discuss in detail how the commoning of urban waterways in Nairobi can be done firstly by using a commons yardstick to evaluate past, current, and future management scenarios, and secondly by using a Commons Identi-kit to demonstrate how commoning can be achieved.

6.2 The problem of hierarchical water resource management in Kenya

Literature reviewed and discussions held with residents and key informants revealed that the management of water resources in Kenya has adopted a centralised hierarchical structure. Discussions with residents of Mathare 4B about who should be responsible for the management of urban waterways produced mixed reactions. Some residents felt that the community should play a stewardship role while most felt that this is the responsibility of government agencies. It was also surprising that no resident mentioned the WRMA as a key government agency responsible for urban waterways. This is despite the fact that, firstly, the WRMA really is the key government agency in charge of all water resources in the country, and secondly, the WRMA is spearheading the ARRP, as discussed in chapter 3 of this thesis. This shows that the WRMA's presence in the informal settlements has not been felt for some reason, and it could be said that the organisation may not have attempted to actively engage residents in the restoration of urban waterways.

Having shown little awareness of the WRMA, the residents identified the National Environmental Management Authority (NEMA), the Nairobi City County Government (NCCG), and the National Youth Service (NYS) as the key government agencies that have been known to, or should, play a role in the management of urban waterways in Nairobi. They also mentioned the United Nations Environmental Programme (UNEP) as having once facilitated a river clean-up exercise in the settlement. As NEMA was seen as the key agency due to wide publicity of environmental conservation issues in the country, the residents felt that it was NEMA that should play the biggest role in cleaning up the Mathare River, facilitating the rehabilitation of a minimum-width riparian zone as well as sensitising communities on the importance of river conservation. Residents felt that the NCCG is responsible for providing sanitation and solid waste services to all city residents and hence plays an indirect role in the conservation of urban waterways. This is because inadequate sanitation and solid waste management increases the vulnerability of urban waterways to pollution. On the other hand, the NYS undertakes programmes which are part of the national development plan (NYS, 2017). Recently, the NYS has been undertaking civil works and environmental maintenance in informal settlements. The presence of the NYS has been felt by residents of Mathare 4B as the agency is currently expanding access roads and helping collect garbage in the settlement. This was a new finding which I was also able to observe firsthand during my fieldwork.

The above-identified government agencies form the structure under which the management of urban waterways is done in Kenya. However, the centralised, hierarchical management structure for water resources in Kenya cannot be said to be the cause of continued water resource degradation in Nairobi. This is because water resources are managed in a similar way in many other countries, including New Zealand, with varying levels of success. Two major problems relating to the water management structure in Kenya were identified through fieldwork and the literature reviewed. Firstly, IWRM management principles adopted in the country have not worked for complex urban areas. Secondly, the government agencies have failed to actively engage urban communities in the management of urban waterways.

The WRMA prides itself in having adopted IWRM principles as prescribed by the GWP following the Dublin Conference of 1972. The WRMA has therefore used this approach to formulate catchment and sub-catchment plans for river basins around the country. The WRMA has attempted to involve local communities in managing water resources, mainly in rural areas, through the use of Water Resource Users Associations (WRUAs). However, the WRMA seems to be playing a passive role when it comes to urban waterways in Nairobi, having not implemented any meaningful project aimed at rehabilitation. Currently, due to public outrage, the WRMA has drafted a proposed restoration programme for the entire Athi River Basin. This programme was formulated to fit in with the IWRM framework by attempting to collectively address all problems within the Athi River Basin in a single project. This has been identified as a major shortcoming of IWRM by scholars such as Giordano and Shah (2014) and Biswas (2004). They observe that IWRM plans, such as what the WRMA has proposed, assume homogeneity of a region and contain vague, broad objectives which may be unimplementable. I support this critique as the Athi River Basin features a variety of landscapes with a variety of socio-cultural, economic, environmental, climatic, and political characteristics whose water problems cannot all be solved by an ‘umbrella solution’. Having such a wide-scoped plan can achieve nothing more than a metaphorical use of the IWRM model, as Ostrom (2015) put it.

Another problem with centralised hierarchical water governance in Kenya is bureaucracy and the abuse of power. A discussion about this was triggered when a resident of Mathare 4B highlighted an isolated case of a well-known and revered environment minister, with high integrity, by the name of John Michuki. It could be said that he is the only minister in the history of the country who attempted to rehabilitate Nairobi’s urban waterways and actually achieved concrete results. This minister pushed his officers to deliver on their jobs, and for

once, a stretch of the Nairobi River Basin was successfully rehabilitated – and, indeed, is maintained up to date. An excerpt from an article in the *Daily Nation* newspaper (December 9th 2009) discusses this success story:

> Environment minister John Michuki on Wednesday received an international recognition for his efforts to redeem the Nairobi River. The United Nations Environmental Programme presented the minister with a certificate recognising his efforts to clean the river, which had been rendered lifeless by human and industrial waste. He received the award in Basel, Switzerland, during a UNEP convention on the control of movement of toxic waste, which he attended last month. When he embarked on the rehabilitation of the Nairobi River in April, few believed that water would ever cascade through the meanders of the city's densely populated slums. Only months later, that is happening. The director for environmental and Conventions at UNEP, Mr Bakari Kante, praised his 'leadership and commitment to global environment', adding that no one had raised courage to face the Nairobi River issue. Presenting the certificate, he said: 'Here is a man who looks beyond short-term ambitions, and acts for future generations; someone who is not driven by short-term interest, but by public interest.' (Juma, 2009)

Unfortunately, the minister leaving office marked the end of urban waterways rehabilitation in Nairobi. One way to interpret this is that if that particular minister was able to get the job done, why have the many others that followed him failed miserably? There is a clear connection here with abuse of office or negligence on the part of government officials, who are paid millions in taxpayers' money and yet fail to perform their duties.

Misappropriation of public funds is nothing new in Kenya; if anything, it is the order of the day, as evidenced by corruption stories in newspapers on an almost daily basis. According to Transparency International's Corruption Perceptions Index for 2016, Kenya's, rank of 145 out of 176 countries, placed it in the top 30 list of most corrupt countries in the world. This is a fact that cannot be disputed, as evidenced by the current president of Kenya, Uhuru Kenyatta, expressing frustration on live television that his efforts to fight corruption were not yielding meaningful results (Transparency International, 2014). The forms of corruption prevalent in Kenya include petty and bureaucratic corruption, grand forms of corruption, and political corruption (Transparency International, 2014). In regard to this thesis, a relevant example pertaining to corruption in the water sector in Kenya is shown below. It involved the Minister of Water who served at the time John Michuki was in the Ministry of Environment.

> Minister of Water Charity Ngilu was investigated in 2011 for corruption allegations directed at her ministry, including forgery, and double payments for goods and services, tax evasion, irregular awards of tenders and nepotism. Also implicated in the scandal were her son-in-law and the husband of the assistant minister for tourism but charges were dropped in October 2014. (Transparency International, 2014, p. 4)

Although the charges were dropped due to lack of evidence, there is no indication that the lost funds were ever recovered or that whoever was responsible for these acts was ever brought to justice. Such examples demonstrate that it is highly likely that funds set aside for urban waterways management may be lost in outright embezzlement, as evidenced by the systemic corruption prevalent in the country. The sharp contrast between these two ministers in the Ministry of Water and Ministry of Environment is an indication of misappropriation of funds according to the integrity of the individual in charge. Unfortunately, it seems that mostly persons with little or no integrity have found their way into management positions, and only one in Kenya's recent past was able to make a difference in urban waterways mangement. It is also ironical that after being cleared of the corruption charges at the Ministry of Water, Charity Ngilu was appointed the country's cabinet secretary for Lands and is currently suspended and under investigation due to yet another corruption scandal (Ogemba, 2015).

The analysis of the proposed budget for the ARRP also demonstrates that over 90% of funds will not go towards concrete rehabilitation processes but rather government processes. Against this background, respondents felt that urban communities cannot be expected to be stewards of urban waterways when there is so much impunity for misappropriation of funds within the organisations that are supposed to be managing the waterways. The respondents pointed out that it is only fair that responsible government agencies lead by example, and only then would urban communities be motivated to take responsibility for the urban waterways as well. Unfortunately, systemic corruption in the country and, probably in the government agencies responsible for water resource management, represent the most intractable issues. It is also one of the most difficult issues to tackle as echoed by our current president, Uhuru Kenyatta.

Attempting to integrate water resource management activities, especially between government, agencies is a time-consuming as well as costly process, as pointed by Mitchell (2005). Integration may deprive resources from more important tasks in a project. I explain this by discussing the budget estimates for the WRMA's proposed ARRP. Although the

estimated budget for this programme is 2.5 billion Kenyan shillings, a closer analysis of the budget breakdown reveals that only 100 million Kenyan shillings seems to be allocated for actual river clean-up campaigns and wetland restoration, or a meagre 4% of the proposed budget. The remaining 2.4 billion Kenyan shillings, representing 96% of the budget, has been allocated to what I would call extremely vague and 'bureaucratic' activities such as development of plans and corporate social responsibility programmes, engaging county governments in waste management, capacity building of WRUAs, and strengthening the capacities of implementing institutions, among others. From this budget, we are able to see government bureaucracy at its best as well as how costly integration can be.

It is also important to mention that such vague action plans with no concrete outputs present an opportunity for misappropriation of funds and are the reason why funds rarely get to the local levels where the actual implementation should be done. This was a view presented by youth group members in Mathare 4B, and one which I also support. The youth members observed that even as they attempt to do the little bit of river cleaning they can (for free), they lack protective clothing and other necessary tools to enable them do a safe and effective job. All the while, money which could be used to these ends and even pay the youth a minimum allowance is getting channelled to such vague activities as (directly quoted from the budget in Appendix A) classification of water resources and setting the resource quality objectives (200 million Kenyan shillings) and developing and implementing an enhanced enforcement programme (25 million Kenyan shillings).

Using Mitchell's definition of IWRM in which he classified management at three levels, I attempt to trace a path of water resource management funds and action plans in Kenya starting from the normative level, down to the strategic level, and finally to the operational level. I have done this by using the proposed ARRP implementation action plan budget as a practical example. The normative level for this case is the entire Athi River Basin. Attention at this scale, as observed by Mitchell (1990), should be on 'what ought to be done', something that the proposed ARRP has failed to clearly articulate, instead only offering generalised discussions and objectives which could be applied to any part of the world. The budget has been formulated at this scale and does not show any breakdown into specific activities at the subsequent lower levels. Therefore, we have a massive budget at the top level that highlights vague, general activities with no specific locations where they will be implemented. At this top level, we do not have a clue as to what will happen at the subsequent middle, strategic level, which is represented by Nairobi city.

The strategic level, as explained by Mitchell (1990), is about 'what can be done', in this case for urban waterways in Nairobi. However, the proposed ARRP does not even mention Nairobi city or any other area, instead repeatedly alluding in general terms to the Athi River catchment. It is here that we clearly start losing sight of the objectives as well as the proposed budget funds. This is because there is no mention of urban waterways in Nairobi which is where the vast majority of pollution is generated. There is also no budget as nothing in the ARRP is budgeted for urban waterways in Nairobi anyway. By the time we get to the bottom – and most crucial – part of this proposed programme, the operational level, the objectives and associated funds may be nothing more but mere illusions. The operational level, which for this thesis can be viewed as the case study area, Mathare 4B, is all about 'what will be done'. This is where concrete activities should be implemented to rehabilitate and stop pollution of urban waterways. However, this is something that cannot be imagined under the ARRP as there is no context, no mention of Nairobi, and no mention of the city's informal settlements or even the sewage treatment plant.

Fundamental questions arise as a result of this. For example, under this budget, what amount of money is allocated for the Mathare River, under which regional action plan, and for what activities? Can and do funds really reach the bottom, local levels where they are supposed to be used for implementation? It is highly unlikely that the answers to these questions could be provided by not only WRMA but also other government agencies operating under a similar hierarchical framework. It could be assumed that this top-down approach is one of the major reasons why urban waterways in Nairobi have continually been degraded over the years with due abandon. Proposed rehabilitation programmes such as ARRP – and their associated budgets – almost completely fail to reach the bottom, operational levels – as represented in this thesis by Mathare 4B. Therefore, the 'what will be done' never gets done as it is unknown and undefined at the top, normative level. In addition there will probably be no money left to do it as it will all get spent, again at the top, normative level, to plan, sensitise, and increase the capacity of central government agencies amongst other top-priority regional activities.

This is a glaring shortcoming of the IWRM approach and the top-down, hierarchical, centralised management of waterways as currently applied in Kenya. Attempts to adopt the IWRM model in Kenya can therefore be said to have led to nothing more than a metaphorical use which has led to unimplementable and vague policy prescriptions (Biswas, 2004; Giordano & Shah, 2014; Mitchell, 1990; Ostrom, 2015). With the centralisation of power,

rarely does anything from the top get to the bottom unless the people at the top facilitate or allow it to. And this is why John Michuki, the outspoken former Minister of Environment, is remembered by the youth of Mathare 4B: he went against the grain, and for once something from the top got to the bottom and the people realised that it was possible. This approach could therefore be seen as leaving the fate of urban waterways and other water resources to the discretion of the top decision-making government officials. But the question is, how many of these government officials will have the integrity and courage to deal with the real problems at the local levels like John Michuki did?

Government agencies in charge of water resources in Kenya have attempted to provide for 'public participation' or the involvement of all stakeholders in water-related issues. A closer examination of how this is interpreted reveals another gap which has generally led to the exclusion of communities in decision-making process. I use the example of 'public participation' as envisioned in the Kenya Water Act which provided for the establishment of the WRMA. The Water Act provides, in my view, a bureaucratic definition of 'public consultation' which entails the publishing of water management–related notices in the newspapers and on national radio to invite comments from the public. This seems more like the government having already decided what needs to be done, for instance through the ARRP as discussed above, and asking people to comment on it.

Using this approach, there is no way of ascertaining that comments and objections raised are even considered, let alone incorporated into the final plans. In addition, this view is based on the assumption that affected people either read newspapers or listen to the radio and are well informed to be in a position to contribute. To make matters worse, the Water Act further provides for arrangements to be made for the general public to obtain copies of water-related documents at 'a reasonable cost'. These uncertainties suggest that 'public consultation' has been interpreted on the contrary to exclude, rather than include, general public participation in formulating water management strategies in the country. Furthermore, residents of Mathare 4B who participated in this study were not only unaware of the WRMA's existence but also of the proposed ARRP. This shows that whatever methods the government has used for 'public consultation' have not reached a better majority of informal settlement residents in Mathare 4B.

The phrase 'public consultation' does not entirely capture the spirit of active engagement of urban communities in the management of urban waterways; in my view it should be replaced

with ‘public engagement’. This is because the aim is not to consult with the public but rather to have them actively engaged and involved in the management process as equal key decision-makers and actors. Actual ‘public engagement’ would entail involving the people in the planning and budgeting processes of the proposed ARRP as well as in its implementation – and this is not happening. In a nutshell, the aggregation of these uncertainties in the current interpretation of ‘public consultation’ only leads to the objective conclusion that the idea is just a policy prescription and a public relations gimmick which has not been used for the actual engagement of urban communities in water resource management but rather to fulfil conditions of ‘supporting agencies’, as posited by Giordano and Shah (2014) and discussed in chapter 3. General water resource management in the country is therefore solely left to the discretion of the ministers in charge of water and environment.

6.3 Adopting a non-hierarchical management approach for urban waterways in Kenya

In response to the shortcomings of the hierarchical and centralised water resources management structure in Kenya, I explored a different approach based on systems theory. I considered adaptive cycles and the panarchy concept as a systems way of conceptualising the urban waterways pollution phenomenon in Nairobi, as discussed in chapter 3. Panarchy is seen as a relevant and suitable concept for representing the urban waterways pollution phenomenon as a linked social-ecological process with complex governance challenges. Panarchy is different from traditional conventional hierarchies as control is not just exerted by larger-scale, top-down processes but also from small-scale, bottom-up processes, thus emphasising cross-scale linkages where processes at one scale affect those at other scales. This is contrary to the current Kenyan hierarchical structure where control is mainly exerted through larger-scale, top-down approaches. I begin this section by presenting the urban waterways pollution phenomenon in Nairobi as a panarchy/nested adaptive system. This is based on the field data obtained as well as the literature reviewed in this thesis.

6.3.1 The pollution of urban waterways in Nairobi as a panarchy

As discussed in chapter 3, in the sustainability framework of a panarchy, all stakeholders are seen to affect the management of urban waterways in one way or another. The role of government agencies responsible for management of the waterways is equally as important as the actions and perceptions of communities living adjacent to the waterways. The relationship between urban waterways on one hand and urban communities including management

agencies on the other hand, is complex and dynamic, often leading to conflicts between the two systems – the socio-economic system and the biophysical system. The socio-economic system in this case is represented by urban land uses while the biophysical system comprises the waterways. To capture this complex relationship I have used the panarchy framework to highlight the different spatial-temporal scales of the urban waterways pollution phenomenon. The panarchy framework incorporates all the stakeholders in this phenomenon and attempts to reveal the gaps that have led to the continuous degradation of urban waterways notwithstanding some government efforts.

It is important to point out that I have chosen to use general descriptions to develop a framework of adaptive change that is hardly a theory but rather a metaphor to help interpret the urban waterways pollution phenomenon and its persistence over the decades. There are three geographical scales to be considered for the sustainable management of urban waterways in Nairobi based on fieldwork data and the literature reviewed. They include:

1. The settlement level – represented by the Mathare 4B settlement, which is the case study area, and the Mathare River, which flows through the settlement.
2. The city scale – represented by the entire city and including all the urban waterways flowing through the city.
3. The regional scale – represented by the wider Athi River Basin, which receives all waters from the Nairobi River Basin.

For each of the scales identified above, I have explained all the phases of the adaptive cycle individually to create an in-depth understanding of what happens at each level. The urban waterways pollution phenomenon in Nairobi is presented as a panarchy in figure 22 below. The panarchy follows a systematic sequence whose phases have been numbered to represent the pollution phenomenon, from the conceptualised first phase (numbered 1) to the final stage (numbered 11).

6.3.1.1 The settlement scale (Mathare 4B and the Mathare River)

The conceptualisation of the pollution phenomenon in this thesis begins at the settlement level, at Mathare 4B, the case study area. The first phase at this level is the *exploitation phase* (figure 22, phase 1). In this phase, there is discharge of solid waste and human waste into the Mathare River due to inadequate sanitation infrastructure and solid waste management services. The residents of Mathare 4B also have no strong value system attached to the waterway, as identified during fieldwork. The second phase is the *accumulation phase* (figure

22, phase 2). As a result of inadequate sanitation infrastructure and solid waste management, the waste that is discharged into the Mathare River accumulates, increasing microbial loads and degrading the river.

The adaptive cycle then moves on to the *disturbance phase*. Continued pollution of the Mathare River leads to water quality thresholds being exceeded through the presence of excessively high counts of microbial pathogens such as *E. coli* and total coliforms, as established in the water sampling survey results presented in chapter 5. Once limits are exceeded, the water becomes non-potable and cannot be used for recreational or consumptive uses. There is still a chance of a dilution effect as the river flows downstream, all factors held constant. The final phase is the *reorganisation phase* (figure 22, phase 11). This phase presents an opportunity for remediation to rectify the situation. This could entail maintaining water quality thresholds at the settlement level by stopping the discharge of solid and human waste through the provision of sanitation infrastructure and solid waste services. For this to be sustainable, it would also entail creating a stronger value system for urban waterways through active community involvement in the planning and implementation of rehabilitation efforts. Failure to do this, as is the current situation, leads to the system transforming into an alternative state – in this case degradation – leading to the destruction of aquatic ecosystems and poor water quality for human use.

At this level, we note that informal settlement residents are vulnerable as a result of inadequate sanitation infrastructure and solid waste management services. The residents further have to contend with haphazard and congested development and a lack of space for minimum standard sanitation facilities such as pit latrines. This vulnerability results in discharging into the Mathare River as the cheapest and most convenient means of getting rid of solid and human waste. Only a few community ablution blocks in Mathare 4B are connected to the sewer and these do not have the capacity to adequately serve all residents. The critical variables for water quality at this level are mainly microbial pathogens from human waste and other forms of domestic solid wastes.

6.3.1.2 The city scale (Nairobi city and the rivers within)

Having traversed the settlement, Mathare River flows into the larger Nairobi River, shifting the conceptual framework into a higher, larger scale – the city scale. This marks the beginning of another adaptive cycle. The *exploitation phase* at the city scale is characterised by the discharge of various types of waste in different urban waterways throughout the city.

Types of waste discharged in other urban waterways include chemicals and heavy metals from industries in the city, solid waste and sewage from formal and informal settlements in other regions of the city, and partially treated sewage from the city treatment plants. The level of pollution in each case is subject to infrastructure and service provision as well as enforcement from concerned agencies, especially in the case of industrial pollution. The adaptive cycle then moves on to the *accumulation phase* (figure 22, phase 4). Inadequate infrastructure and weak enforcement leads to the accumulation of chemicals, heavy metals, and microbial pollutants throughout the Nairobi River Basin, further degrading water quality in the urban waterways.

The *disturbance/release phase* (figure 22, phase 5) at the city scale is characterised by continued accumulation of wastes leading to critical thresholds for water quality being exceeded. This leads to destruction of river ecosystems in the city, high risks of disease outbreak due to bacterial pathogens, and loss of the recreational value of urban waterways. The water is non-potable and cannot be used for domestic consumption or irrigation purposes. Despite this, urban agriculture within the city uses this water for irrigation, exposing consumers of the agricultural products (mainly vegetables) to diseases from bacterial pathogens, chemicals, and heavy metals taken in by the plants. The adaptive cycle then moves on to the *reorganisation phase* (figure 22, phase 10). This phase presents an opportunity for sustainable adaptive management on the part of the city through provision of proportionate infrastructure and services for all human settlements to manage solid waste as well as sewage. This would entail the construction of a new wastewater treatment facility (or the expansion of current ones) and the serving all city residents equally with sanitation infrastructure and solid waste collection services. Other management activities would include improved enforcement to curb industrial pollution and exploring alternative paradigms and technologies for conserving urban waterways, such as ‘commoning’ and river tunnelling respectively.

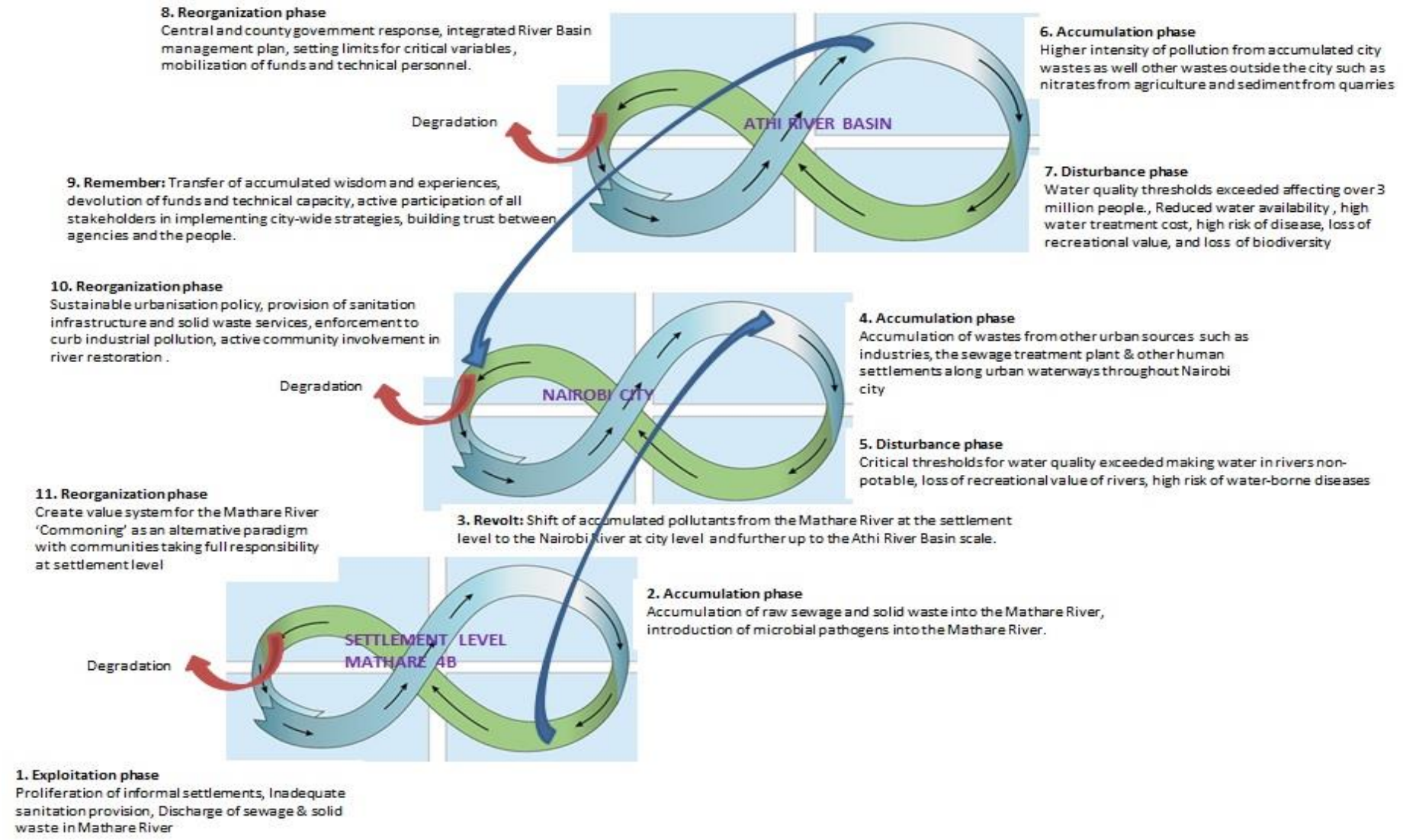


Figure 22: The pollution of urban waterways in Nairobi as a panarchy

At this scale, the pollution phenomenon is compounded by the combination of pollutants from other informal settlements and other land uses in the city. Of importance to mention are the industries which introduce chemical and heavy metal contaminants as well as the city sewage treatment plants which discharge into rivers within the city effluent which has only been partially treated (Musyoki et al., 2013). Previous studies conducted in Nairobi by authors such as Maingi et al. (2013) and others have revealed that there is little or no dilution effect at play as pollution is seemingly continuous along the river continuum. An opportunity arises during the heavy rainfall season for flash floods to cleanse the rivers, but this is not effective because urban run-off usually mixes with sewer line effluent and carries more solid waste from the land into the rivers. Immediately after the floods, the whole pollution cycle resumes, soon returning the river to its former degraded state.

Some of the key informants interviewed pointed out that pollution at the city scale occurs with impunity where industries required to treat effluent before discharge fail to do so while the monitoring and enforcement agencies like NEMA have failed to deal with them effectively. Grand plans for river restoration have been made, as discussed earlier, but implementation seems not be taking off, and may actually not be possible. This is due firstly to the complex heterogeneous social, political, and economic dynamics which have not been considered by the current top-down management structure, and secondly to the emphasis on wide-scope general objectives aimed at large-scale catchment management, as prescribed by IWRM guidelines, rather than specific local area–based action plans. These factors were identified in the previous section on the hierarchical management of urban waterways in Nairobi as the major roadblocks to the sustainable management of urban waterways. The critical variables at this scale have been extended to include chemicals and heavy metals, the same as for the Athi River Basin scale, as shown in table 5 below.

6.4.1.3 The regional scale (Athi River Basin)

The Nairobi River collects waters from all other waterways in Nairobi city before it drains into the larger Athi River outside the city. The Athi River is the second longest river in Kenya at a length of 591 km and draining a basin area of approximately 39,000 km^2 (WRMA, 2016). The adaptive cycle for the Athi River begins with the *exploitation phase*. At this phase, all rivers coming from Nairobi empty their waters polluted by the city into the Athi River. In addition, there is pollution from other sources outside the city boundaries, such as quarries which add sediment into the river and farming activities contributing nitrates and phosphates as well as pesticides into the river. The pollution problems at this scale may be

attributed to lack of knowledge (on sustainable farming), inadequate sanitation services and infrastructure, and poor water governance. The adaptive cycle then moves on to the a*ccumulation phase* (figure 22, phase 6). At this phase, degradation occurs at a much higher intensity due to the cumulative effects of human activities at a larger geographic scale. This leads to accumulation of all sorts of pollutants in the Athi River: chemicals, heavy metals, nutrients, microbial pathogens, pesticides, sediment, and solid waste.

The continued accumulation of these wastes in the Athi River leads to the *disturbance phase* (figure 22, phase 7). At this phase, the pollution impacts are felt by a larger population of over three million people downstream of the city. These people are in an arid and semi-arid region and rely on water from Athi River for daily domestic consumption, and as such are adversely affected by the waterways pollution. This is because almost all water quality thresholds have been exceeded and the water is no longer potable. The dilution effect is negligible due to continuous water pollution at different points along the river continuum. As a result, there is reduced water availability for users, a high risk of contracting water-borne diseases, high water treatment costs, loss of recreational value, and loss/disturbance of the river's ecological system. Disturbance of the river ecology means that there are reduced fish stocks and even, in extreme cases, species extinction.

The Athi River system then moves on to the *reorganisation phase* (figure 22 phase 8), where there exists opportunities for remedial action to deal with pollution within the Athi River Basin. Technical assistance and expertise from central government agencies is vital at this stage through regional river development authorities such as the Tana and Athi Rivers Development Authority (TARDA), the environmental agency (NEMA), the WRMA, and the governments of counties through which the Athi River flows. The idea is for these agencies to collaborate and identify key areas to be addressed collectively rather than continuing with the stand-alone approach that has been adopted in Kenya. This is a situation whereby each individual agency has its own strategy of dealing with the problem independent of other active agencies in the Athi River catchment. It leads to replication of activities, inter-agency conflicts, and waste of scarce resources. Leadership is important at this scale to come up with a sustainable river basin management plan that articulates clear strategies for management at the subsequent lower geographic scales. It is also at this point where all agencies involved should pool their allocated water resource management funds and ensure that it goes towards implementation of concrete outputs. This is because as long as funds continue to be misappropriated at this level, the urban waterways pollution problem will persist.

The sustainability threat for Athi River at this scale includes the entire range of water quality standards, as shown in table 5 below. If water quality is compromised through contamination from the wastes discussed above then the river will have been degraded. The critical management variables at this scale are water quality standards for different classes of pollutants such as microbial pathogens, chemicals, and heavy metals. Maintaining critical variables at a minimum ensures that water quality is maintained for both ecological instream processes and human consumption without adverse health impacts. The water quality standards for sources of domestic water in Kenya as set out in table 5 below represent the critical variables at this level.

Table 5: Quality standards for sources of domestic water (source: NEMA, 2006)

Parameter	**Guide value (maximum allowable)**
pH	6.5-8.5
Suspended solids	30 mg/l
Nitrate-NO_3	10 mg/l
Ammonia-NH_3	0.5 mg/l
Nitrite-NO_2	3 mg/l
Total dissolved solids	1200 mg/l
E. coli	nil/100 mg/l
Fluoride	1.5 mg/l
Phenols	Nil mg/l
Arsenic	0.01 mg/l
Cadmium	0.05 mg/l
Lead	0.05 mg/l
Selenium	0.01 mg/l
Copper	0.05 mg/l
Zinc	1.5 mg/l

Once these quality standards have been exceeded, it is an indication of river degradation through pollution. As previous studies have established, most of these critical variables for the Athi River have been found to be alarmingly high (Kithiia, 2012; Maingi et al., 2013). Sampling data for this study specifically focussed on microbial pollution. Results obtained showed that *E. coli* counts were well over the limit, which, according to table t above, is

ideally nil/100 ml, with the recorded counts at various sampling points ranging between 400 cfu/100 ml to over 10,000 cfu/100 ml, a clear indication of adverse degradation.

The panarchy framework for urban waterways pollution in Nairobi as depicted in figure 22 above represents a collapsed system that has failed to reorganise at each level, thus leading to continual degradation of the waterways. Fundamental questions therefore arise as to how sustainability can be achieved in the system. The answers to these questions are found in the connections between the different adaptive cycles represented by the 'revolt' and 'remember' connections, shown as numbers 3 and 9 respectively in figure 22 above. Inter-connections between the adaptive cycles are the key to system recovery and sustainable management of the waterways. The 'revolt' and 'remember' connections are crucial towards achieving sustainability within the panarchy framework, as discussed in the next section.

6.4 Nesting the urban waterways pollution phenomenon in Nairobi towards achieving sustainable management

The individual adaptive cycles from the different geographical scales highlighted above can be combined into a panarchy. This is referred to as nesting. There are potentially many connections between phases at one level and phases at another level, but the most important of these are the 'revolt' and 'remember' connections. This is because they determine the sustainability of the entire system. For urban waterways in Nairobi, revolt occurs when the adaptive cycle at the settlement level enters its disturbance phase of creative destruction leading to degradation of Mathare River. This degradation cascades into the city scale adaptive cycle when the Mathare River empties accumulated waste into the Nairobi River (shown as number 3 in figure 22 above). This triggers a crisis at the city scale level where the adaptive cycle is at its accumulation phase and resilience is low due to the presence of other pollutants from industries and other urban land uses. The revolt therefore suggests that fast and small processes at the settlement level overwhelm large and slower processes at the city level as a result of continual pollution from different sources.

The revolt can also represent a positive transfer of influence from the smaller scale to the larger scale. For instance, the efforts of the youth groups in Mathare 4B to rehabilitate the Mathare River at the settlement level constitute a positive influence that can be transferred to the city scale, encouraging more efforts from other urban communities. This transfer of positive influence is what maintains the integrity of the entire system. On the other hand,

upward transfer of negative accumulated materials, such as pollutants, is what leads to system collapse, in this case degradation.

The remember connection, on the other hand, is the downward arrow from higher scales to lower ones. It is viewed as important in times of change and renewal. The remember connection is shown as number 9 in figure 22 above. In a panarchy, the smaller, faster scales such as the city level are seen to be protected by the larger, slower scales such as the the Athi River Basin through the remember connection. For this case, once a catastrophe is triggered at the city level, the opportunities and constraints for renewal are organised by the accumulation phase of the Athi River Basin, which is the subsequent higher and larger scale. This is based on the premise that larger and slower scales have accumulated wisdom and experiences of maturity, for instance, in relation to how the entire Athi River has previously been successfully managed and conserved even before colonisation and the rapid development of the country. At this point, we begin to recall and examine things such as how our ancestors managed the waterways communally and how they managed to keep them in a pristine condition.

The ‘remember’ back link, therefore, presents an opportunity for system recovery and novelty. Novelty is defined as the creation of new things or new combinations via natural and human processes through the process of innovation (Allen et al., 2014). It relies on understanding the system’s dynamics at different levels in order to institute measures that ensure sustainability throughout the panarchy. In the case of a degraded system such as Nairobi’s urban waterways, novelty presents an opportunity for restoration through actions such as active community involvement, improved access to sanitation infrastructure, and positive collaboration among government agencies. Failure to do this will lead to the system shifting to an alternative state of increased degradation.

Sustainability in a panarchy is therefore maintained by the positive continuous interaction between the adaptive cycles both from bottom to top and vice versa. It is envisioned as a scenario where the larger, slower levels – such as the Athi River Basin – invent, experiment, and test, while the smaller, faster levels – such as the Mathare 4B settlement – stabilise and conserve accumulated memories of past successful experiences, thus making the whole panarchy both creative and conserving (Crawford S Holling, 2001). However, this has not been the case for urban waterways in Nairobi. At the larger levels, central government agencies have failed to provide leadership on sustainable management and have also failed to

appropriately spend waterways restoration funds for actual restorative purposes. This has created mistrust between government agencies and urban communities as well as the disillusionment of residents at the smaller, faster levels. Residents have little motivation to conserve and actively protect urban waterways, thus causing a collapse of the panarchy system, as is evidenced by the continued degradation of urban waterways in Nairobi. The next section therefore addresses how we can contextualise the 'revolt' and 'remember' connections to achieve sustainable management of urban waterways in Nairobi through active community engagement (commoning) and responsible governance.

6.5 'Commoning' urban waterways in Nairobi city

The phenomenon of pollution of urban waterways in Nairobi as a panarchy revealed two critical gaps that have most likely caused collapse of the system leading to continued degradation of the waterways. Firstly, central government agencies have failed to address the issue by adopting wide-focus plans, misappropriating funds, and enacting minimal inter-agency collaboration. Secondly, urban communities have not been included in the management of waterways, leading to the failure of proposed restoration programmes within the Nairobi River basin. To address these gaps, I discussed the practice of commoning as an alternative management approach that could be applied to urban waterways in Nairobi.

Discussions held with residents of Mathare 4B revealed conflicting views about who should be responsible for managing and protecting urban waterways. Some residents felt that it was the government's responsibility since they had all these agencies established particularly for the management of water resources and there were people paid to do the job. Other residents felt that it was the collective responsibility of the urban communities and the relevant government agencies. They observed that urban communities should play a stewardship role while government agencies should provide professional, technical, and financial facilitation. The key informants felt that a human approach should be adopted, which basically meant engaging all communities along the river continuum and making upstream communities conscious of, and accountable for, their actions.

This thesis has revealed that currently the youth groups in Mathare 4B have had some levels of success in their attempts at keeping the waterways clean by managing community ablution blocks and facilitating garbage collection as well as discouraging citizens from polluting the environment and the Mathare River. In addition, they have done this without much help or

facilitation from the government, an indication of how residents can unite to better their lives by placing collective public interests above personal individual interests. The youth groups felt that they would do a better job conserving the waterways if they received technical support from relevant government agencies as well as international agencies such as UNEP. The views and opinions of the residents, youth group members, and key informants strongly point towards an opportunity for commoning urban waterways by actively engaging adjacent urban communities.

6.5.1 Using the commons yardstick to project future scenarios for urban waterways in Nairobi

As discussed in chapter 3, commoning has a strong bearing on sustainability and considers how future generations will be affected by the current use or management of a commons. The current use of the Mathare River as the most convenient and cheapest way of disposing of human and solid waste does not present a sustainable future for the generations to come. To address these sustainability issues when commoning, Gibson-Graham et al. (2013) recommend the use of a 'commons yardstick' to analyse past and present use of a commons and predict future generations' use of it. I attempted to represent past and present management practices for urban waterways in Nairobi in chapter 3, figure 14. In this section I attempt to project future scenarios based on current management practices and alternatively on a commoning practice. It is important to note that the commons yardstick helps in the analysis to identify not only the kinds of ethical actions needed to enhance sustainable management of a commons but also those that have not worked in the past.

The first scenario is based on continued management of urban waterways under the current disjointed, wide-scope, bureaucratic, centralised government hierarchy. The alternative scenario is based on commoning and responsible governance involving active participation of urban communities as well as positive involvement of government agencies. This is depicted in figure 23 below.

The upper part of the commons yardstick shown above represents significant time periods in the history urban waterways management in Nairobi and corresponding water quality status. The pre-colonisation era (numbered 1 above) is a representation of the situation of waterways in Nairobi before colonisation. The name 'Nairobi' is derived from a Maasai phrase, *enkare nyrobi*, which translates to 'cool water' (GoK, 2017). The colonisalists encountered the Maasai, a semi-nomadic pastoralist people in south-west Kenya who grazed their cattle in

open landscapes. The colonialists adopting this name for its capital city is evidence of the pristine condition of waterways in the area before Nairobi city, as we know it, was established. At the time of colonisation, communities living in Kenya followed a traditional way of life and natural resources such as waterways were managed collectively by the communities.

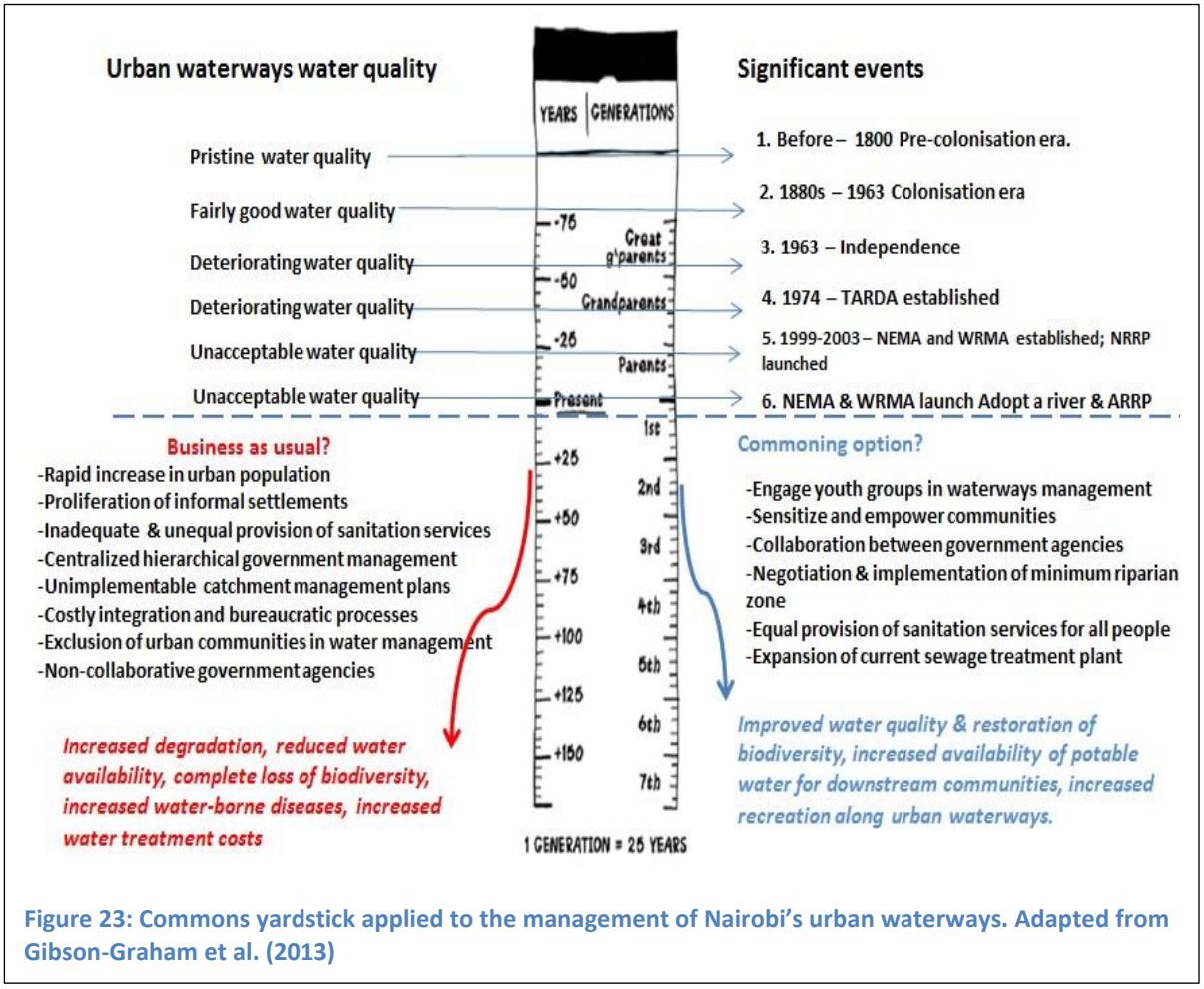


Figure 23: Commons yardstick applied to the management of Nairobi's urban waterways. Adapted from Gibson-Graham et al. (2013)

The colonisation era (numbered 2 above) represents the period when the country was taken over by British colonialists beginning in the 1880s and many indigenous African tribes were chased off their ancestral lands and confined to government reserves (as were the Aboriginal people in Australia as explained in chapter 3). The country was now open to exploitation by the British imperialists, who cleared large tracts of land to conduct large-scale farming. This was the period when urban centres began to be established, including Nairobi, chosen as the capital. The availability of many rivers which could supply clean, fresh water to the British imperialists and Indian labourers building the railway line was a major factor in choosing Nairobi's location (GoK, 2017). With colonisation, the management of natural resources

shifted from traditional community customary practices to a centralised colonial government and the influence of international market forces. This is a significant period as it marked the installation of a new system of capitalism and the collapse of traditional African community management practices. It could also be seen as the time when the waterways flowing through the newly established capital began to come under pressure.

The period after independence (numbered 3 above), which took place in 1963, represents the period when the country gained independence from Britain and Africans were now free to move out of the colonial settlement reserves. It is a period that was marked by rapid urban population growth and poor management of urban areas as well as the city's water resources. With Nairobi increasing in population, there was a proliferation of informal settlements. The government attempted slum demolition in the 1970s, as pointed out by Githira (2016), but did not succeed due to public outrage. The government then viewed the informal settlements as illegal and made the decision not to provide them with sanitation infrastructure and services such as sewage and solid waste management. This is the period when things went from bad to worse for the urban waterways in Nairobi as informal settlements started discharging raw sewer and solid waste into the waterways. As a result, pollution in the waterways became significant, with water quality thresholds being exceeded not only for microbial contamination but also chemicals and heavy metals from industrial activities. There was no significant government response.

The establishment of the Tana and Athi Rivers Development Authority (TARDA) in 1974 (numbered 4 above) marks the start of another important period. TARDA was given jurisdiction over the entire Athi River Basin, which includes the Nairobi River Basin. It went on to facilitate the construction of various dams and implemented irrigation schemes in the region, as well as undertook conservation activities. Despite this, it never addressed the escalating pollution problem within the Nairobi River Basin, and so the pollution continued unabated. TARDA had the earliest chance to take a leadership role in conserving Nairobi's waterways, but it never did.

It was not until 1999 that NEMA was established to combat environmental pollution in the country (numbered 5 above). A few years later, in 2002, the first exclusive water management agency in the country, the WRMA, was formed. With the establishment of these two organisations, there was renewed hope for Nairobi's waterways. However, current pollution levels indicate that the two government agencies have not had any significant

impact over the 15 years they have been in operation. The urban waterways are as polluted as they were 15 years ago, if not worse. In section 6.2 of this chapter I addressed the reasons why these two major agencies failed, especially – among other shortcomings – their centralised, hierarchical management structure.

The most recent significant period (numbered 6 above) is represented by the current proposed restoration efforts on the part of the WRMA in the form of its Athi River Restoration Programme (ARRP) and NEMA in the form of its Adopt-A-River initiative. These two programmes have been critiqued in chapter 3 of this thesis as unimplementable and unreplicable respectively. Even as these ambitious programmes are rolled out, Nairobi's waterways continue to face unprecedented pollution, and the community engagement, components of these initiatives especially in 'worst-case scenario' areas such as informal settlements, continue to be nothing but a public-relations gimmick. The current situation is thus characterised by a top-down, highly centralised management approach.

Below the present generation line, I have depicted two scenarios, dubbed 'Business as usual' and 'Commoning and responsible governance option'. Business as usual represents a situation where the management of urban waterways continues to be structured as it is today. This is characterised by proposed grandiose central government programmes that have no particular focus on addressing specific waterways problems at specific locations. These programmes have also not developed an adequate framework to actively engage urban communities in management of the waterways. The scenario also features a continued increase in the urban population and the proliferation of more informal settlements characterised by unequal service provision. Under this scenario, which is what has been happening since independence, we should not expect to see any positive changes in the urban waterways. Instead, we should expect pollution to continue to increase, which will lead to yet further reduced water availability, the total annihilation of biodiversity within the entire Athi River Basin, increased water-borne diseases which could lead to increased child mortality, and increased water treatment costs to make the water usable.

The alternative scenario discussed is the commoning and responsible governance option, which advocates for a bottom-up approach actively engaging urban communities in urban waterways management with lead government agencies playing a facilitation role. Community youth groups such as Ghetto Rangers in Mathare 4B provide an entry point for the commoning practice of urban waterways. They have demonstrated that they are willing to

sensitise and mobilise urban residents to protect urban waterways and only need to be empowered in terms of knowledge and equipment. Responsible governance entails lead government agencies such as WRMA and NEMA providing their technical support as well as allocating government funds to enable such groups to be effective in their work to conserve urban waterways. It is also at this point that city authorities, in conjunction with urban communities, can work towards equal provision of sanitation facilities and solid waste management services. In conjuction with the commoning process, it is also vital for the government to undertake the speedy expansion of existing sewage treatment plants since the urban population for Nairobi is projected to continue growing at a rate of approximately 4% per annum. The sewage treatment plants must have the capacity to treat increased volumes of human waste due to increased increased sewer connections as they eventually redischarge the water as treated effluent into the waterways.

Under the commoning and responsible governance option scenario, it is assumed that the degradation of urban waterways will start reducing and results may be visible to the next generation, 25 years from now. The adoption of commoning will lead to the creation of a value system for urban waterways and in effect a community-formulated protocol for the management of urban waterways. The urban communities will pass down these values to the next generation and also decide how to share in the benefits of urban waterways for activities such as recreation and even domestic consumption once water quality standards are achieved. The communities will be stewards of the waterways and will also agree amongst themselves as to how to deal with residents who pollute the water resources. All the while, using Kenyan taxpayer funds, lead government agencies will collaborate to ensure that they provide leadership and facilitate the activities of these urban communities. Concerted efforts by lead government agencies will ensure no replication of activities and also no general, vague, unimplementable programmes. Under this scenario, urban waterways will flourish and support biodiversity as they once did, there will be increased water availability for use by downstream communities, and the waterways will be of positive use to the urban communities.

6.5.2 Commoning urban waterways in Nairobi

Commons require some rules for management based on the collective agreement and responsibilities of the users involved. As discussed in chapter 3, for effective commoning of a resource to occur, it is critical that there be a ‘we’: a community that establishes how

commons are to be managed (Gibson-Graham et al., 2013). In regard to this study, that 'we' means the Mathare 4B residents living adjacent to the Mathare River. In addition, the rivers represent interconnected commons which are shared by other communities along the river continuum. Downstream users are also thus part of the 'we' communities that have been adversely affected by the actions of communities upstream. Therefore, it is important that all communities along the Nairobi and Athi river continuum adopt commoning and view themselves as positive contributors to the way the rivers are accessed, used, benefited from, cared for, and taken responsibility for, as pointed out by Gibson-Graham et al. (2013).

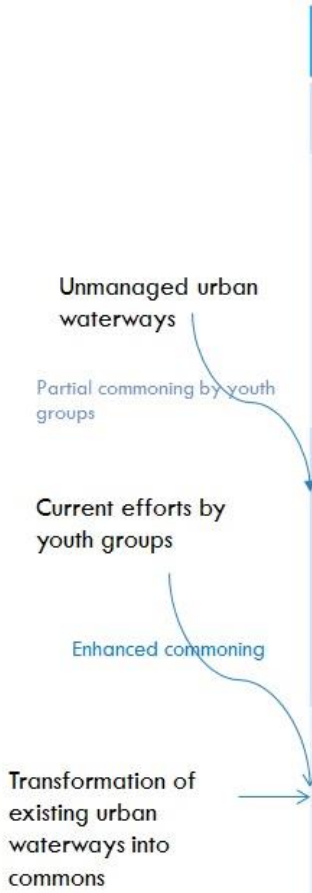
This thesis has revealed that youth groups in Mathare 4B have to some extent taken responsibility for the Mathare River, both directly and indirectly. Some of the indirect ways they have done this is by providing alternative sanitation options to discourage 'flying toilets' and defecation on the river banks. They have done this by operating and maintaining clean community ablution blocks which are an alternative to other means of human waste disposal that expose the river to pollution. These youth groups have also taken it upon themselves to manage solid waste in the settlement. They do this by providing garbage bags to residents which are then collected from each household after they are filled and placed at a strategic point for collection by city authorities. In the process they discourage residents from dumping solid waste in the river. The youth groups have directly participated in river clean-up exercises and cited one success story where they collected piled-up solid waste in the Mathare River under one of the footbridges and convinced residents not to dump in that area; there has been no dumping there since then.

The future of commoning for urban waterways in Nairobi is therefore not about creating new commons but rather about supporting and empowering the youth groups (and other organised community groups) and spreading the principle of commoning throughout the city. Active youth groups dealing with sanitation and environmental issues such as the ones in Mathare 4B provide a good entry point to pursue the collective management of urban waterways. They have demonstrated that despite all the challenges and frustrations expressed by some residents about the failure of the central government's management approach, there is hope, and people just have to start with what little they have. It is therefore possible to provide for the commoning of urban waterways in the city using an incremental approach by starting with what organised community groups are already doing, no matter how inconsequential their activities may seem. This incremental approach to commoning could be spread to other parts of the city by involving other actively organised community groups.

The Commons Identi-kit, presented in chapter 3, can be modified into a commoning tool appropriate for the situation in Nairobi. This would help identify opportunities for commoning by maintaining the existing commoning practices being undertaken by the youth groups and building on these towards a total transformation of the poorly managed urban waterways into commons. This thesis has already established that some form of commoning already exists, and so the objective would be to intensify the commoning process for urban waterways by further empowering organised urban communities such as the youth groups. This would ensure that these communities participate actively in the sustainable management of urban waterways in the city. Figure 24 below demonstrates how a complete transformation of urban waterways into commons can be achieved.

Effective total transformation of urban waterways in Nairobi into commons would entail having unrestricted but responsible access to urban waterways for recreational uses and consumption. Currently, access is open to various land uses, but as discussed earlier, this has mainly been for the discharge of human, solid, and industrial waste. Through commoning, urban communities such as the residents of Mathare 4B can create a value system for urban waterways that ensures sustainable management for the benefit of the community. The youth groups have started to put into place some new kinds of norms about care and responsibility for the environment and the waterways through their various initiatives. This was shown in figure 24 as 'current efforts by youth groups'. It would therefore be easy to build on what is already being done by the youth groups and other community residents.

The use of urban waterways in the city has largely been a consequence of the level of infrastructure provision, including sanitation and solid waste services in informal settlements along riparian zones; it has also largely been a consequence of enforcement regimes of pollution regulations, especially for industrial effluent and treated sewage discharge from city treatment plants. We can therefore not ignore the role of relevant government agencies in remedying the pollution dilemma. As part of complementing the commoning process to shift away from these negative uses, enforcement agencies such as NEMA and WRMA must crack down on industrial pollution as well as hold city authorities accountable for effectively treating sewage before discharging it into the rivers. The NCCG must also at this point work with all urban residents to improve sanitation provision and solid waste management in the city. It does not have to implement huge, costly infrastructure projects to improve the situation; instead, co-production of community sanitation infrastructure, as discussed by Elinor Ostrom in chapter 2, would provide a good starting point.



The commoning urban waterways in Nairobi						
	ACCESS	**USE**	**BENEFIT**	**CARE**	**RESPONSIBILITY**	**PROPERTY**
Overall current situation	Settlements, industries, markets, etc.	Open & unregulated; mainly waste disposal	No perceived benefits in city; used by 3 million people downstream	None (govt agencies?)	None (govt agencies?)	Open access State?
Minimal youth group efforts for the Mathare River	Mathare 4B residents	Attempted youth groups regulation – discouraging residents from dumping wastes	Need for a clean and healthy environment for residents	Some efforts by youth groups	Some efforts by youth groups	Open access
Desired situation	Unrestricted but responsible	Responsible use by all riparian residents	City residents & downstream users	Communities & agencies	Communities & agencies	Open access

Figure 24: The Commoning urban waterways in Nairobi

This would entail building on whatever small efforts are already being made and gradually eliminating any temporary substandard infrastructure that residents are currently using to empty human waste into the river and gradually improving the situation through connection to sewer lines. Labour would be provided by the residents substantially reducing the implementation costs. The youth groups in Mathare 4B have also shown a commitment to collecting solid waste within the settlement, and so the only thing to be done by authorities is ensure that they regularly collect the waste at a designated point; they do not have to go round the settlement as the youth groups are already doing this. This was something that residents of Mathare 4B felt strongly about, pointing out that any restorative efforts taking place before improvement of sanitation and solid waste management would only serve to address the symptoms and not than the root causes of urban waterways pollution.

Currently, the urban waterways are of no perceived benefit to urban residents, as pointed out by respondents during fieldwork. This is because they are already highly polluted and cannot be used for recreation and consumption purposes. However, downstream communities do rely on water flowing from the urban waterways for various uses. In addition, it can be assumed that once water quality starts to improve in the urban waterways, urban residents can accrue various benefits, such as a recreational value and even the possibility of consuming the water. A total transformation of urban waterways into commons would therefore provide benefits not only to downstream users but also to urban residents. The youth groups in Mathare 4B have shown a sense of responsibility by attempting to keep the river clean even though currently they get no benefits from the river. This to some extent shows that they feel responsible for preserving water quality for downstream users. It is this sense of public responsibility that would ensure effective commoning throughout the river continuum – considering the interests of downstream communities as a starting point.

Therefore, for effective commoning to occur, as shown in figure 24 above, care and responsibility must be provided by urban communities, with the help of relevant government lead agencies such as the WRMA and NEMA. Currently, care and responsibility is perceived to lie with the government agencies; yet after reviewing the commoning yardstick for urban waterways in Nairobi, we can conclude that these agencies have not had any significant impact since the country gained independence. If anything, efforts by youth groups seem to have had the most success despite the fact that they lack knowledge, tools, and financial capacity. Therefore, for effective commoning, care and responsibility must be bestowed on the urban communities who interact with the waterways on a daily basis and who have a

strong sense of community, as demonstrated by youth groups in Mathare 4B. Government agencies should provide technical and financial support to urban communities at the local level to ensure sustainability of the commoning process. This would mean shifting budget allocations from bureaucratic processes to empowering urban communities already engaged in urban waterways conservation. For instance, the proposed ARRP has a budget allocation of up to 250 million Kenyan shillings for developing and implementing a management plan to realise resource quality objectives within the Athi River Basin. It makes no sense to have a budget that high for a group of technocrats to sit and come up with a plan as to how to manage urban waterways while youth groups at the grassroots level are already addressing the real challenges for free. Even 10% of the budget allocated for coming up with the plan would be enough to empower youth groups by providing them with the necessary tools and equipment they require in their conservation activities. It would also be enough for a minimal upgrade of sanitation facilities in the settlement; youth groups pointed out that they require assistance to renovate the ablution blocks. Government priorities in terms of urban waterways management must focus on empowering the communities to do it themselves rather than on sustaining a costly bureaucratic process that will not achieve any results.

As urban waterways are open-access resources, they meet one of the criteria for commoning, as shown in figure 24 above. In conclusion, we note that urban waterways have gradually transformed from their pristine condition into a state of high degradation in less than a hundred years as a result of rapid development and the abandonment of community management practices. Central government response has been ineffective in addressing this problem, and continuing 'business as usual' will only make the situation worse. Therefore, commoning presents an opportunity for managing urban waterways differently. In essence, it represents a nod to the pre-colonial Kenyan ancestors whose social management practices seem to have kept the waterways pristine, what I have previously termed as 'going back to our roots' (Nilsson & Nyanchaga, 2009). Notwithstanding extraneous variables such as rapid urbanisation and the role of central government agencies, urban communities are up to the challenge, as demonstrated by the youth groups in Mathare 4B and as posited by Ostrom in her statement that "communities of individuals have relied on institutions resembling neither the state nor the market to govern some resource systems with reasonable degrees of success over long periods of time" (Ostrom, 2015, p. 1).

There is no documented evidence of river pollution in pre-colonial and pre-independent Kenya, when waterways were treated as common goods and socially managed through

collective community initiatives (Nilsson & Nyanchaga, 2009). This supports Elinor Ostrom's position as stated above. It is time that the country explored other ways of managing urban waterways through strong community collective responsibilities as our ancestors did to keep the water in our rivers clean. Now more than ever, with unprecedented population increase throughout the country and the challenges of climate change, we need every drop of water available to deal with the acute water shortages facing the country.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

Why are urban waterways in Nairobi facing continuous degradation, and what are the effects on city residents and downstream communities? This thesis has revealed that the pollution phenomenon in urban waterways in Nairobi results from a combination of various factors. Firstly, the city has undergone unsustainable urbanisation trends characterised by poverty. Secondly, informal settlements have proliferated without adequate sanitation and solid waste management provision. Thirdly, governance has been poor because of an ineffective hierarchical and bureaucratic management structure. Fourthly, provision of sanitation infrastructure has been inadequate not only in informal settlements but throughout the city. And lastly, but most importantly, urban communities have been excluded from the management process in regard to urban waterways. The thesis has determined that that the pollution effects have been devastating to both urban and downstream communities. These have led to the loss of the rivers' recreational value in the city, the loss of biodiversity in the rivers, reduced water availability for use and consumption in downstream areas, and an increased risk of contracting water-borne diseases through contact with or consumption of the water.

As a result of the failure of the conventional hierarchical, centralised government management system, I explored how a panarchy framework might be applied to the problem, one which recognises inputs from all stakeholders in the management of urban waterways for system sustainability. Panarchy is a relevant concept that can represent the urban waterways pollution phenomenon as a linked social-ecological process with complex management challenges. The panarchy framework fosters the 'revolt' and 'remember' connections between smaller and larger systems, which I have argued are vital for the sustainable management of Nairobi's waterways. These two connections were identified as the major gaps in the current management structure, as discussed in chapter 6. Using the panarchy framework, I explored the idea of 'commoning' Nairobi's urban waterways to address the pollution problem.

This thesis revealed that youth groups in the case study area, Mathare 4B, have attempted to engage in sanitation improvement, solid waste management collection, and clean-up of the adjacent Mathare River. These groups' small-scale efforts in some sense could be as seen as commoning – prevention of pollution of the Mathare River by providing residents with alternatives for sanitation and solid waste management as well as the physical river clean-up. If anything, I have argued that the youth groups' actions have been more successful in the

recent past than the combined efforts of government agencies, which have yielded policy documents and plans that are hardly implementable with hardly any concrete results. Even without knowing it, the youth groups have adopted the idea of communally managed sanitation, and opportunities exist for the co-production of sanitation in Mathare 4B, starting with what the youth groups have done so far and building on that, as argued by Dombroski (2015), Ostrom (1996), and Schouten and Mathenge (2010). Rather than wait for donor aid or government help for the provision of sanitation infrastructure, these groups have taken it upon themselves to do the best they can with the little they have as long as the community enjoys a cleaner environment.

This chapter presents my final thoughts based on the literature reviewed, the research methodology, and the primary data I collected. It also presents recommendations as to how urban waterways could be managed sustainably through the empowerment of community groups and a commitment to responsible governance from central government agencies and NGOs. The chapter also discusses the theoretical and methodological contribution of this study. And finally, it proposes areas for further research.

7.1 Reflections on methodology

This thesis adopted a case study design incorporating mainly qualitative methods and with quantitative methods playing a complementary role. The qualitative aspect focused on the exploration of how and why urban waterways are polluted and the perceptions and attitudes of informal settlement residents and key informants. In my opinion, the focus groups and interviews with the residents of Mathare 4B yielded rich data in terms of understanding their perceptions of and interactions with urban waterways. The data obtained further revealed interesting findings about the role of the youth groups towards the protection of the Mathare River through innovative initiatives such as providing alternative sanitation and solid waste management options to discourage residents from polluting the river. In this respect, a qualitative approach encompassing a case study for in-depth analysis was successful in addressing the research objectives.

On the other hand, the proposed interviews with key informants were not as successful as the focus groups and interviews with residents. The response rate to my interview requests was low and only yielded four interviews, two of which were with university lecturers: indeed, out of five key government agencies identified for interviews, only two agreed to participate.

Notwithstanding this shortcoming, I was able to review available policy documents outlining the current role that all relevant agencies are playing in the management of urban waterways.

The quantitative aspect of the study was successful in confirming high faecal contamination of urban waterways in Nairobi, as had been revealed by earlier monitoring exercises for other studies. The quantitative findings confirmed that raw sewage was being discharged in the urban waterways not only from informal settlements but also from other, more affluent neighbourhoods as well as from the city's sewage treatment plant. The two methods therefore played a complementary role in creating an in-depth understanding of the dynamics of urban waterways pollution in Nairobi.

The results obtained through this methodology can be generalised to other informal settlements along urban waterways in Nairobi as they have similar characteristics and face more or less the same challenges in terms of insecure land tenure, congestion, inadequate sanitation and solid waste services, and marginalisation by city authorities due to their being brushed aside as illegal. The findings of this study can therefore be applied to these other settlements towards fostering a sustainable management of urban waterways at a city-wide scale.

7.2 Theoretical contributions of thesis

The panarchy theoretical framework has previously been applied in conceptualising complex ecological systems such as large forests, semi-arid savannah ecosystems, and aquatic ecosystems – their development, growth, and decay. This thesis has, for the first time, attempted to apply this framework in conceptualising the urban waterways pollution phenomenon in Nairobi as a linked social-ecological system. In so doing, the thesis has captured the complexity of the issues involved in the management of urban waterways at different geographical scales from the settlement level all the way up to the Athi River Basin level (regional scale). The panarchy framework has successfully demonstrated that all actions at all scales make a significant contribution towards sustaining the system and preventing collapse.

System sustainability is achieved in a panarchy mainly through the 'revolt' and 'remember' connections within the panarchy, which allow for bottom-up and top-down interactions respectively. Using the panarchy framework, the thesis has demonstrated that the current system has collapsed leading to widespread degradation of waterways throughout the Athi River Basin. The collapse is attributed to weak or negative connections between different

scales. For instance, the 'revolt' connection seems to be transferring accumulated pollutants from the settlement level to the city scale rather than sparking effective community management activities. Likewise, the 'remember' connection has failed to provide leadership from government as well as accumulated wisdom and experiences that can help in sustainable management of urban waterways. Therefore, the envisioned panarchy for urban waterways in Nairobi is doomed to remain trapped in a perpetual state of collapse unless the positive connections within the system are activated.

This thesis has also incorporated commoning practice theory to build on what the youth groups in the study area are already doing. The thesis has argued that current efforts by youth groups to self-organise for the sake of improving the condition of Mathare River by providing better sanitation and solid waste management alternatives can be viewed as a commoning of the Mathare River. This is because their activities substantially reduce the amount of pollutants entering the river from the settlement and constitute a collective community initiative. It is the position of this thesis that an entire commoning of Nairobi's waterways can be achieved by empowering community groups which are already engaged in improvement of sanitation, solid waste management, and river clean-up. Likewise, central and local government authorities need to recognise that costly projects are not necessarily required to improve sanitation and solid waste management in informal settlements. These objectives could be achieved through a co-production of sanitation infrastructure, where residents gradually improve on what they have according to their economic means with the help of these agencies.

7.3 Summary of conclusions

From the summary of findings, the study concludes that urban waterways have been perceived by residents of informal settlements as the most convenient and cheapest way of disposing of sewage and solid waste. The perceptions and attitudes of residents towards Mathare River revealed that the residents of Mathare 4B have little sentimental attachment to the river and instead view it merely as a convenient and cheap way of disposing their waste. The reasons given for this were that firstly, the settlement lacked an effective solid waste management system, and secondly, it lacked adequate sanitation infrastructure in terms of ablution blocks and a municipal sewer connection. Literature reviewed also revealed that 87% of residents in the Mathare informal settlement are tenants and thus have no ownership rights to either the structure they live in or the land they occupy. I have argued that this also reduces the sentimental value residents attach to their settlement and subsequently to the

adjacent Mathare River. Thus, as temporary residents, they feel little or no obligation to care for or improve the structure, land, and adjacent river. The systemic corruption prevalent in Kenya has also led to the disillusionment of informal settlement residents reducing their willingness to care for urban waterways as they feel that relevant management agencies have been misappropriating funds for waterways management. They therefore feel that government agencies must lead by example for ordinary citizens to feel encouraged towards participating in the sustainable management of urban waterways. Key informants interviewed were in agreement that poor urban planning had in large part contributed to the proliferation of informal settlements along riparian zones and also acknowledged that urban waterways traversing informal settlements are highly polluted as a result of disposal of solid waste and raw sewage.

In regard to how the pollution of urban waterways is affecting downstream communities, the study concludes that pollution within the city has had negative adverse effects on downstream communities. This was supported by the water sampling field data which revealed high microbial contamination levels in the Mathare, Nairobi, and Athi Rivers. This data revealed high counts of microbial pathogens (*E. coli* and total coliforms) well above recommended national standards for both fresh river water and treated sewage effluent. Overall, the results of the water samples obtained confirmed that urban waterways in Nairobi are highly polluted from the discharge of raw sewage. Even the lowest counts of *E. coli* and total coliforms recorded for this study – 400 and 3700 cfu/100 ml respectively – were way over the limit of Kenya's national standard of nil cfu/100 ml. Therefore, the excessively high levels of *E. coli* and total coliforms recorded in Nairobi's waterways has rendered the water non-potable and poses a great health risk for downstream users who use the water for recreation, irrigation, and other consumption purposes.

This research also concludes that the current water resource management structure in Kenya is unsustainable and cannot effectively address the urban waterways pollution dilemma. The country has adopted a centralised, hierarchical management approach which excludes urban communities from the management process. Public participation as currently envisioned in the Water Act of 2002 serves little more than the metaphorical use of the phrase. In addition, the country has subscribed to integrated water resource management (IWRM) principles as prescribed by the Global Water Partnership, and this has led to formulation of highly generalised, wide-scope, unimplementable strategies for the management of urban waterways. Another major shortcoming of the IWRM approach is that it is costly to integrate,

with the upshort being that most funds set aside for urban waterways restoration programmes are lost in government bureaucratic processes.

Against all odds, youth groups in Mathare 4B have attempted to prevent pollution of urban waterways following the failure of relevant government agencies to fulfil their mandate. They have engageged in Mather River commoning by providing alternative sanitation options as opposed to flying toilets and open defacation which leads to river pollution. They have also attempted to physically rid the river of solid wastes through river clean-up as well as discouraged residents from dumping by offering to collect wastes at a small fee. They thus currently represent, in my opinion, the only meaningful effort aimed at preventing pollution of the urban waterways in the city.

On the other hand, Nairobi City County Government (NCCG) agencies in charge of sanitation provision and solid waste management have marginalised the informal settlements, thus leaving them with no sewer line connections, inadequate ablution blocks, and dismal solid waste services. In regrad to the precarious poverty situation in informal settlements, the proposed sewer connection to these settlements may not be affordable to residents who are required to pay connection fees as well as monthly charges. This well meaning project may therefore fail to improve sanitation in these settlements leading to continued degradation of the waterways. Lastly, as a result of an unsustainable central government management approach to the waterways and its marginalisation of informal settlements, urban waterways have become more vulnerable to pollution.

7.4 Recommendations

In response to the current urban waterways pollution dilemma, the study recommends a systems approach that conceptualises urban waterways management as a nested adaptive cycle (panarchy). The study recommends the use of a panarchy system for the following reasons: firstly, panarchy is a relevant and suitable conceptual means of representing the urban waterways pollution phenomenon as a linked social-ecological process with complex governance challenges; secondly, panarchy is different from traditional conventional hierarchies because control is exerted not just through larger-scale, top-down processes but also through small-scale, bottom-up processes; thirdly, the use of the panarchy framework will ensure that all the stakeholders are incorporated into urban waterways management, maintaining strong interlinkages between the small and large scales; and lastly, the panarchy framework strongly emphasises sustainability within the system, which is achieved by the

positive continuous interaction between the adaptive cycles from the bottom to the top and vice versa. The panarchy framework thus provides for the sustainable management of urban waterways by incorporating the needs and inputs of all stakeholders, in particular, the urban communities adjacent to urban waterways.

To effectively restore and maintain urban waterways, the sanitation and solid waste management challenge must be dealt with. This thesis has revealed that the communal sanitation option represents the best chance for informal settlements to have decent sanitation, as argued by Schouten and Mathenge (2010). Currently, communal santitation is in use in Mathare 4B and is under the management of the interviewed youth groups. This presents an opportunity for co-production of sanitation between informal settlement residents and the NCCG. Rather than embark on costly sanitation projects that residents may not be able to afford to connect to or maintain, the NCCG should negotiate possible ways of improving what is currently available with the active participation of residents. The same approach should be used for solid waste management.

The youth groups have taken it upon themselves to gather wastes generated in the settlement to leave at a designated point for collection by the NCCG, yet collection is rarely done. The thesis recommends that the NCCG complements the efforts of such youth groups by regularly collecting the waste they gather out of the settlement. This is because when left uncollected for long, the waste ends up in the river. No grandiose and costly upper level projects are required from government agencies to remedy the sanitation and solid waste management challenge. Gradually building on what community groups are already doing and empowering them in terms of technical and financial assistance would go a long way in improving sanitation and solid waste management in informal settlements – and subsequently reducing pollution in the city's waterways.

Commoning, in combination with co-production and the implementation of communal sanitation facilities, represents the best chance for restoring the urban waterways and reducing pollution. This is against a background of central and county government initiatives which have failed to address this complex dilemma. The study has adopted the assumption that the only time water resources in Nairobi may have been unpolluted is during the precolonial era, when it was under the management of traditional Kenyan communities. The current situation also reveals that current community initiatives such as those by the youth groups in Mathare 4B are the only ones that seem to be addressing the problem,

inconsequential though they may seem. Collective management of urban waterways in Nairobi through commoning is therefore recommended as the most sustainable way of managing these waterways. It presents a chance for the waterways to rejuvenate and be of use to both urban residents and downstream communities, especially at a time when the country is faced with acute water shortages. The recommended commoning of urban waterways in Nairobi should take advantage of what organised community groups are already doing, and through an incremental approach, forge on towards total commoning.

Central and county government agencies must also adopt responsible and accountable governance in their management approach to complement what the citizens are already attempting to do to reduce pollution in the city's waterways. The study therefore recommends collaboration between government agencies engaged in the management of urban waterways so as to provide a united front towards ending their pollution. This is also one way of pooling different government agencies' resources together in a bid to strengthen concerted efforts and ensure the sustainability of proposed programmes. However, this will not solve any problem if over 70% of management funds are lost in bureaucratic processes. Therefore, government agencies need to shift their focus from bureaucracy and 'over-planning' to concrete action at the grassroots levels. To minimise bureaucracy, the government agencies need to identify water-specific problems in specific areas first and then work towards finding practical solutions, whether they apply IWRM principles or not. This would entail formulating more specific plans dealing with water-specific issues at specific localities rather than the current wide-scope, generalised catchment-level plans that do not address any specific issues.

Another way of eliminating bureaucracy and enhancing sustainable management of urban waterways is through community empowerment to facilitate an effective commoning of the urban waterways. If youth groups such as Ghetto Rangers in Mathare 4B are empowered with the right tools and knowledge as well as minimum finances, they would effectively kick-start a total commoning of urban waterways at the local settlement level. Their involvement in urban waterways management will sustain the process as they are also residents and will own the process as well as encourage other community members to join in. Therefore, restoration funds which at the moment are mainly lost through government bureaucratic processes should be channelled towards commoning initiatives throughout the city.

This thesis has concentrated mainly on creating an in-depth understanding of the urban waterways pollution phenomenon in Nairobi in regard to its informal settlements. It has

reviewed the role of residents as well as of government agencies. It has also explored different management approaches based on the panarchy framework and on active community engagement with the recommendation that commoning and co-production of sanitation infrastructure should be adopted in informal settlements to reduce pollution levels. An interesting topic for future research based on the study findings could be to explore in further detail, ways of formulating a comprehensive framework for the commoning of urban waterways in Nairobi.

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Appendices

Appendix A: Proposed budget for the Athi River Restoration Programme

Sub Programme	Project areas	Responsible Stakeholders	Timeframe	Budget (Million Ksh)
To ensure adequate water quality and quantity for basic human needs and ecological functions.	Upgrade and automate water quality and quantity monitoring network	WRMA, development partners, WRUAs,		100
	Undertaking water quality and quantity assessments	WRMA, County Governments, Development partners		150
	Classification of the water resources and setting the Resource Quality Objectives (RQOs)	WRMA, Development partners, and all other stakeholders		200
	Development and Implementation of a management plan to realize the RQOs	WRMA, Development partners, and all other stakeholders		250
		Sub-Total		700

To protect the water resources against pollution	River clean-up campaign	WRMA and all stakeholders		80
	Conducting abstraction and pollution surveys with a view to preparing water allocation plans and pollution prevention plans	WRMA, Development partners, WRUAs, County Government and all other stakeholders		180
	Wetland restoration and conservation	WRMA, Development partners, WRUAs, County Government and all other stakeholders		30
	Develop and implement an enhanced enforcement program	WRMA		25
		Sub-Total		315

To collaborate with stakeholders on sanitation and solid waste management	Engage County Governments on proper management of solid waste, agrochemicals and sanitation	WRMA and County Governments						3
	Develop and implement a Corporate Social Responsibilty program to involve public and private sector in catchment restoration	WRMA, County Government and all other stakeholders						50
		Sub-Total						53

To enhance water protection capacity	Develop and Implementation of sub-catchment management plans (100 SCMPs)	WRMA, WRUAs and all other stakeholders						800
	Capacity build WRUAs to undertake both on-farm and off farm conservation measures e.g. pegging and vegetating the riverine	WRMA, WRUAs,County Government and all other stakeholders						200
	Develop and undertake an enhanced sensitization and awareness campaign for water users, school children and other stakeholders	WRMA and other stakeholders						40
	Develop and Implement an emergency response plan for pollution control	WRMA, Development partners, WRUAs, County Government and all other stakeholders						30
	Strengthen the capacity (human resources, tools, equipment) of implementing institutions	WRMA, Development partners, WRUAs, County Government and all other stakeholders						300
	Mobilize financial resources for developing a full proposal and its implementation	WRMA, Development partners, WRUAs, County Government and all other stakeholders						10
		Sub-Total						1380
		OVERALL TOTAL						2,448

Appendix B: Informal settlement residents interview guide

1. What are your perceptions about the Nairobi River?
2. Is the river of any use to you and the community?
3. If yes, what use?
4. In your opinion, why is the river highly polluted?
5. What are the major ways through which the river is polluted?
6. Are there currently any efforts to reduce pollution of the river?
7. How can the community be involved to reduce the pollution levels of the river?
8. What else needs to be done in order to reduce river pollution and by whom?

Appendix C: Key informants (professionals and scholars) interview guide

1. What is the mandate of this organisation in regard to urban waterways in Nairobi?
2. What are the current uses of urban waterways traversing informal settlements?
3. How do these current uses affect water quality for downstream communities?
4. What are the major causes of pollution of urban waterways traversing informal settlements?
5. What is this organisation currently doing to reduce pollution of urban waterways in Nairobi?
6. What measures should be put in place to reduce pollution of these waterways?
7. Discuss the current management structure of urban waterways in Nairobi and the roles played by different authorities and stakeholders.
8. In your opinion what should be the ideal management structure and what role should each stakeholder play in managing urban waterways to reduce pollution?
9. How are urban waterways managed effectively in other countries to avoid pollution? Methods and approaches… top-down or bottom-top?
10. What are the challenges and opportunities available when it comes to managing and restoring polluted urban waterways?

Appendix D: Community focus group discussion questions guide and oral script

Project Title: Perceptions of informal settlement dwellers on urban waterways and their impacts on water quality for downstream users: Case Study of Mathare 4b Village, Nairobi, Kenya

Student: Kevin Kienja

Hello. My name is Kevin Kienja. I am a master's student in the Department of Geography/Waterways at the University of Canterbury. I have called this focus group to discuss the pollution of the rivers which flow through informal settlements.

Before we begin, I would like to take a few minutes to explain why I am inviting you to participate and what will be done with the information you provide. You will be asked to participate in a focus group discussion. The main issues to be discussed in this focus group will include:

- A brief history of the settlement,
- The changes that have occurred over time in terms of housing, service provision, and land tenure,
- The challenges faced by residents and opportunities they perceive,
- How people relate with the river,
- Why they relate this way with the river,
- How you think people should relate with the river,
- What people use the river for,
- What you feel are the major issues leading to pollution of the rivers,
- What you think should be done to improve the situation,
- How you think it should be done and,
- Who should be responsible for the rivers?

The information obtained from this focus group will be used for academic purposes. I may also use this information in articles that might be published, as well as in academic presentations. The individual privacy of all participants and **confidentiality of the information** provided will be maintained in all published and written data analysis resulting from the study. **The entire focus group discussion is confidential**. Participants have a choice to either use their real names or pseudonyms with any quotes attributed to the discussion.

The focus group should take between 1 and 2 hours. Please understand **participation is entirely on a voluntary basis** and any participant has the right to withdraw consent or **discontinue participation at any time.** The benefits which may reasonably be expected to result from this study are reduced pollution levels of the rivers and hence a reduction in water-borne related diseases, especially in children.

I would like to tape-record this focus group so as to make sure that I remember accurately all the information provided. I will keep these tapes in secured rooms and they will only be used by the transcriber to type up the discussions. The transcriber has also signed a confidentiality agreement not to disclose any information regarding the discussions.

My research assistant(s) also present here have signed confidentiality agreements not to disclose any identities of participants or information obtained from this focus group discussion.

If you have any questions, you are free to ask them now. If you have questions later, you may contact me at kevin.kienja@pg.canterbury.ac.nz or kkienja@yahoo.com. You can call or text me on 0722881191 up until August 10th 2016 as I will be returning to New Zealand after that. While in New Zealand, you can always contact me on any of my email addresses. If you have any complaints, you

can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

Consent to record the focus group

May I tape-record this focus group discussion?

Consent to quote from interview

I may wish to quote from this focus group either in the presentations or articles resulting from this work. A pseudonym will be used in order to protect the identity of any participant, unless the participant specifically assents to be identified by their true name.

Do you allow me to quote from this focus group?

Consent to take photographs of the focus groups

May I take some photographs to capture the group discussions?

We will now take a short break to discuss any issues you may have before we commence the focus group. If anyone is not willing to participate please feel free to leave.

THANK YOU FOR YOUR TIME

Appendix E: Confidentiality agreements for research assistants and transcribers

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UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Department: Waterways/Geography
Telephone: +64 0220522668 & +254 722881191
Email: kkienja@yahoo.com or kevin.kienja@pg.canterbury.ac.nz

Project Title: Perceptions of informal settlement dwellers on urban waterways and their impacts on water quality for downstream users: Case Study of Mathare 4b Village, Nairobi, Kenya

I …… (Research assistant/transcriber) agree to treat all information and data related to this fieldwork as confidential. I will not discuss or share any information I am privy to with any third party apart from the principal researcher (Mr. Kevin Kienja).

Date: …… Signature ……

Appendix F: Information sheet and Consent Forms for key informants

Information Sheet

Department: Waterways/Geography
Telephone: +64 0220522668 & +254 722881191
Email: kevin.kienja@pg.canterbury.ac.nz or kkienja@yahoo.com
[Date]

Perceptions of informal settlement dwellers on urban waterways and their impacts on water quality for downstream users: Case Study of Mathare 4b Village, Nairobi, Kenya

My name is Kevin Kienja and I am pursuing my Master's degree in Water Resource Management. The purpose of this research is to examine pollution of urban waterways by informal settlements in Nairobi city; the causes, effects, as well as possible pollution management options. The study will further explore informal settlement residents' perceptions of adjacent urban rivers and how this affects water quality especially for downstream communities.

If you choose to take part in this study, your involvement in this project will be discussing your views and opinions on pollution of urban waterways adjacent to informal settlements and how all relevant stakeholders can be involved in improving the situation. The interview will last for a maximum of 45 minutes or less.

Participation is voluntary and you have the right to withdraw at any stage without penalty. You may ask for your raw data to be returned to you or destroyed at any point. If you withdraw, I will remove information relating to you. However, once analysis of raw data starts on June 2016, it will become increasingly difficult to remove the influence of your data on the results.

The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this investigation: your identity will not be made public without your prior consent. To ensure anonymity and confidentiality, no names will be used in the thesis. Only the views and opinions will be expressed and perhaps, where necessary, the titles of professionals interviewed such as 'the environmental planner'. The data is for academic purposes and will be publicly accessible through the University Library. Copies will also be given to relevant government institutions dealing with management of urban waterways upon request. The data will be stored in password protected hardware and will be destroyed within ten years. A thesis is a public document and will be available through the UC Library.

Please indicate to the researcher on the consent form if you would like to receive a copy of the summary of results of the project.

The project is being carried out [*as a requirement for Masters of Water Resource Management* by Kevin Kienja under the supervision of Dr. Kelly Dombroski and Professor Jenny Webster who can be contacted at Kelly.dombroski@canterbury.ac.nz and jenny.webster-brown@ Canterbury.ac.nz. They will be pleased to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Human Ethics Committee, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

If you agree to participate in the study, you are asked to complete the consent form and return to the principal researcher.

Consent Form Template

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Department: Waterways/Geography
Telephone: +64 0220522668
&
+254 721881191
Email: kkienja@yahoo.com

Perceptions of informal settlement dwellers on urban waterways and their impacts on water quality for downstream users: Case Study of Mathare 4b Village, Nairobi, Kenya

- I have been given a full explanation of this project and have had the opportunity to ask questions.
- I understand what is required of me if I agree to take part in the research.
- I understand that participation is voluntary and I may withdraw at any time without penalty.
- Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.
- I understand that any information or opinions I provide will be kept confidential to the researcher and that any published or reported results will not identify the participants. I understand that a thesis is a public document and will be available through the UC Library.
- I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after *ten* years.
- I understand the risks associated with taking part and how they will be managed.
- I understand that I am able to receive a report on the findings of the study by contacting the researcher at the conclusion of the project.
- I understand that I can contact the researcher Kevin Kienja (kevin.kienja@pg.canterbury.ac.nz or kkienja@yahoo.com) or supervisor Dr. Kelly Dombroski (Kelly.dombroski@canterbury.ac.nz) and Professor Jenny Webster Brown (jenny.webster-brown@ Canterbury.ac.nz) for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)
- I would like a summary of the results of the project.
- By signing below, I agree to participate in this research project.

Name:_____ Signed:_____ Date:

Email address *(for report of findings, if applicable)*:

Appendix G: Residents interviews oral script

UNIVERSITY OF CANTERBURY
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CHRISTCHURCH NEW ZEALAND

Department: Waterways/Geography
Telephone: +64 0220522668 & +254 722881191
Email: kkienja@yahoo.com or kevin.kienja@pg.canterbury.ac.nz

Project Title: Perceptions of informal settlement dwellers on urban waterways and their impacts on water quality for downstream users: Case Study of Mathare 4b Village, Nairobi, Kenya

Student: Kevin Kienja

Hello. My name is Kevin Kienja. I am a Masters student in the Department of Geography/Waterways at University of Canterbury. I would like to invite you to participate in a **research study** about pollution of rivers which flow through informal settlements.

Before we begin, I would like to take a few minutes to explain why I am inviting you to participate and what will be done with the information you provide. You will be asked to participate in a short interview. Please stop me at any time if you have questions about the study. I welcome your views on:

- How people relate with the river,
- Why they relate this way with the river,
- How you think people should relate with the river,
- What people use the river for,
- What you feel are the major issues leading to pollution of the rivers,
- What you think should be done to improve the situation,
- How you think it should be done and,
- Who should be responsible for the rivers?

The information obtained from this interview will be used for academic purposes. I may also use this information in articles that might be published, as well as in academic presentations. Your individual privacy and **confidentiality of the information** you provide will be maintained in all published and written data analysis resulting from the study. Participants have a choice to either use their real names or pseudonyms in any quotes attributed to the interview.

Your participation should take approximately 30-45 minutes. Please understand your p**articipation is entirely on a voluntary basis** and you have the right to withdraw your consent or **discontinue participation at any time without penalty.** The benefits which may reasonably be expected to result from this study are reduced pollution levels of the rivers and hence a reduction in water-borne related diseases especially in children.

If at any time and for any reason, you would prefer not to answer any questions, please feel free to skip those questions – say 'skip this question'. If at any time you would like to stop participating, please tell me. We can take a break, stop and continue at a late date, or stop altogether. You will not be penalized for deciding to stop participation at any time.

I would like to tape record this interview so as to make sure that I remember accurately all the information you provide. I will keep these tapes in secured rooms and they will only be used by the transcriber to type the interview. However, it is not compulsory that I tape record the interview. If you feel uncomfortable, I will take notes.

If you have any questions, you are free to ask them now. If you have questions later, you may contact me at kevin.kienja@pg.canterbury.ac.nz or kkienja@yahoo.com. You can call or text me on 0722881191 up until August 10th 2016 as I will be returning to New Zealand after that. While in New Zealand, you can always contact me on any of my email addresses. If you have any complaints, you can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)

Are you interested in participating in this study?

Consent to Record Interview
May I record this interview?

Consent to Quote from Interview
I may wish to quote from this interview either in the presentations or articles resulting from this work. A pseudonym will be used in order to protect your identity, unless you specifically request that you be identified by your true name.

Do you allow me to quote from this interview?

Consent to Use Name
There may be reasons for which you prefer that your true name be used in presentations and articles related to this research.

Would you like your true name to be used in any oral presentations or written documents resulting from this research?

If yes then sign below

Participant's name……..

Participant's signature……..

Date……..

THANK YOU FOR YOUR TIME

Appendix H: Photographs of Petrifilm results and corresponding sampling points

Site 1: before Mathare 4B

Site 2: along Mathare 4B

Site 3: after Mathare 4B

Site 4: Before sewage treatment plant

Site 5: last sewage treatment pond

Site 6: after discharge of treatment plant

Site 7: Fourteen Falls recreational site